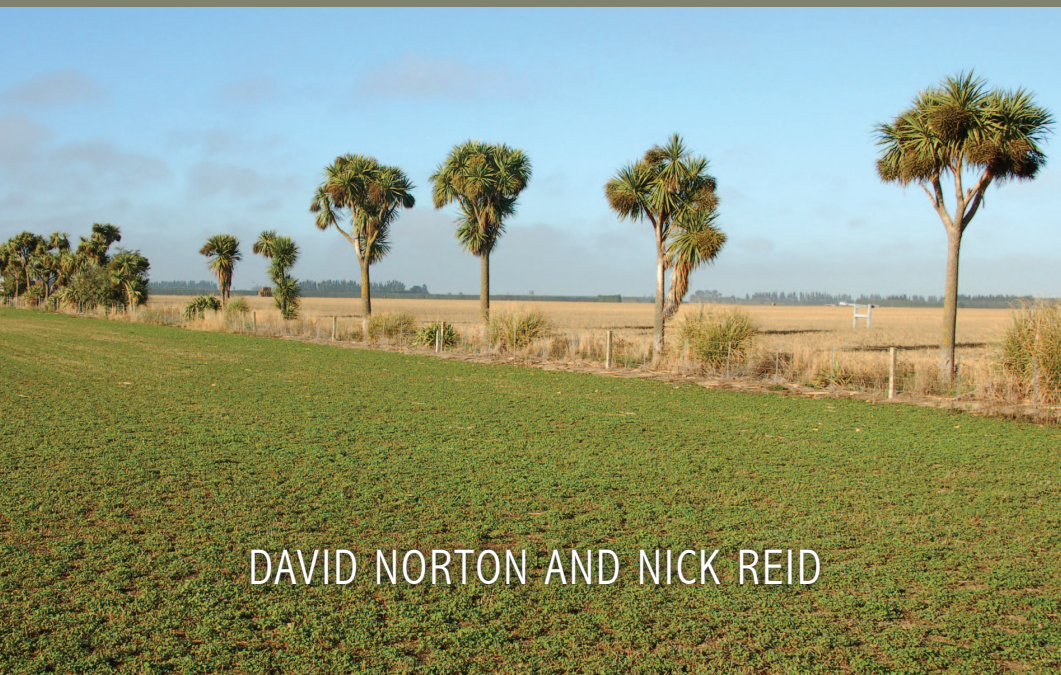




NATURE AND FARMING

SUSTAINING NATIVE BIODIVERSITY IN AGRICULTURAL LANDSCAPES



DAVID NORTON AND NICK REID

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NATURE AND FARMING

for
Hannah, Alice and Mackenzie,
and
Jackie, Ross and Muriel

NATURE AND FARMING

SUSTAINING NATIVE BIODIVERSITY IN AGRICULTURAL LANDSCAPES

DAVID NORTON, UNIVERSITY OF CANTERBURY
NICK REID, UNIVERSITY OF NEW ENGLAND



PUBLISHING

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FOREWORD

Recent commentary suggests that Earth has entered a new age, the Anthropocene, which marks the increasingly pervasive impacts of humans on the world's ecosystems. Despite this, much conservation theory and practice has been based on a view of the world in which human activities and conserved nature are separated as much as possible. In this view, the world is categorised into protected and unprotected areas, habitat and non-habitat, production land and conservation land. Although these categories may still be appropriate in some instances, the scale of the human enterprise and the impacts of climate and land-use change, among other global drivers, mean that a radical rethink of conservation approaches may be needed. Particularly, conservation within human dominated landscapes needs to complement protected area approaches.

This is most obvious in the areas of the world taken up for production of food and fibre. Here, alteration and fragmentation of the landscape is obvious with, often, little of the pre-existing ecosystem remaining. In these landscapes, multiple trends are coalescing to present new conundrums for conservation. The world's growing population, declining amounts of good arable land, the spread of urban areas into agricultural hinterlands, and other forces are leading to a crunch in terms of human food security. Conflicting priorities for growing food and fuel are becoming common. Conserving biodiversity thus has to happen in an increasingly volatile and unpredictable biophysical and social environment.

At the same time, there are positive indications that solutions are possible and that effective conservation

can happen in even the most transformed landscapes. In many different parts of the world, innovative ways of combining production and conservation are being found. In addition new policy and management opportunities, for instance, in relation to carbon sequestration, offer great potential to produce multiple benefits, including useful conservation outcomes.

This book provides a timely overview of both the threats and opportunities involved in maintaining biodiversity in agricultural landscapes. Using the contrasting environments of Australia and New Zealand, David Norton and Nick Reid clearly enunciate the issues involved and back up the more general and conceptual discussions with a set of case studies, mostly but not exclusively from Australia and New Zealand, highlighting recent policy and management initiatives. The case studies provide important examples of what can be done. Indeed, they emphasise just how much is already happening in rural Australia and New Zealand. Most importantly, these case studies showcase the individual farmers and others who are behind them, and show that the farms involved remain highly profitable – highlighting that 'win-win' outcomes are possible. Such examples provide essential beacons for the future and inspiration for others to follow suit. Successfully navigating the future will require serious consideration, development and uptake of the ideas and approaches presented here.

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1

WHY THIS BOOK?

This book is about sustaining native biodiversity in agricultural landscapes. We define native biodiversity as those plants and animals¹ that occur naturally in a region. We distinguish native biodiversity from the plants and animals that people have introduced from elsewhere, such as pasture plants, or have arrived unintentionally, such as rats, from other regions or countries (i.e. exotic or introduced species). In this chapter, we explain the focus of this book and the reasons why we have written it. We discuss why we believe a wide variety of management approaches to sustaining native biodiversity is required

in farmscapes, and outline five principles that are axiomatic if the diversity of native biota is to be sustained in agricultural landscapes.

Why conserve native species in farmland? There are many reasons:

- Native plants, animals, fungi and microbes provide essential services as inputs to commercial production. These services include nutrient cycling, pollination (e.g. in horticulture, legume-based pastures and various annual brassica, cucurbit and legume crops), natural pest control by beneficial



Scattered trees and stands of eucalypts in a South Australian pastoral landscape. (Photo: David Paton)

fauna in intensive production systems (e.g. cotton, vegetables and vineyards) and erosion control

- On many farms, native biota are the resource base or the outputs of production – for instance, the farm business raising livestock on native pastures, or harvesting fish, wildlife, timber or other plant products
- Biodiversity is a treasure trove of genetic novelty and perhaps every organism has some untapped biological potential that might one day, with the right technology, prove crucial to human welfare – who can say?
- Aesthetic and intrinsic qualities of native bush and wildlife make a farm home and, along with the geomorphic landscape, instil the sense of place deeply felt by many landowners, and vicariously by many others in society
- Many native species in agricultural landscapes are threatened with extinction, and some of these can be sustained most easily or are only found in farmland
- Finally, we owe it to future generations to ensure that as close as possible to a full complement of biodiversity on our planet survives into the future.

We have written this book for people who manage or work in agricultural landscapes, including farmers, consultants and agribusiness staff, as well as policy makers, planners, educators, students and scientists.



Eastern North Island farmscape with exotic pasture dominant and native forest remnants.

These people may be farm managers, contractors, workers or employees of government agencies, agribusinesses, educational institutions or non-governmental organisations. We have also written this book for interested laypeople who are passionate about their rural countryside, who are part of local landcare or similar groups, or who simply enjoy rural environments.

We have focused on biodiversity conservation in Australian and New Zealand farmland because we are most familiar with these environments. But we believe that the issues we discuss and our approach to securing and enhancing biodiversity in these farmscapes are applicable to other developed countries, especially in North America and Europe, as there are many similarities with the agriculture practices, market economies and environmental problems of these countries. However, we have not addressed farming and conservation in the developing world as many of the biodiversity conservation issues there, and the solutions to deal with them, are likely to be different to those in the developed world.

Much of the focus of biodiversity conservation since the establishment of the first national parks more than a century ago has been on protected areas (parks and equivalent reserves), with less attention to non-protected areas. The same can be said for ecological research, most of which has been undertaken in non-agricultural landscapes.² The predominant paradigm in the conservation community and in conservation practice has been one of segregated land management³ – preservation in protected areas with resource utilisation elsewhere. However, 38% of the world's land surface is now cultivated (as sown pasture or croplands) and another 27% is grazed as part of the world's drylands.⁴ Furthermore, as the human population is expected to increase by another third to 9.1 billion by 2050,⁵ the demand for agricultural land can only increase. Even within protected areas, considerable areas are being used for or are affected by agriculture, especially in developing countries. As we explain in Chapter 4, the transformation and fragmentation of most of the world's natural areas has disastrous implications for planetary biodiversity. Human modification of the biosphere has set in train an extinction spasm that will rival the mass extinction events that have befallen the planet over the past 3.5 billion years, such as the 'Great Dying' at the end of the



The Canterbury Plains, one of the most intensively farmed areas in New Zealand, with very little residual native biodiversity.

Permian or the Cretaceous–Tertiary meteor strike in the Gulf of Mexico that saw the demise of the dinosaurs and the end of the Cretaceous.⁶

As we discuss in the next chapter, landscapes dominated by agriculture contain a significant proportion of the world's biodiversity, especially as agriculture is most intensive and extensive on the most productive parts of the land surface. Applying a protected area approach to biodiversity conservation in these landscapes is not practical because there is often little left to protect, because the demand for food and fibre and the nature of land tenure means that preservation is not an option, and because the changes that have occurred to these landscapes are such that, even in remnant natural areas, traditional approaches to protected area management often don't work. For these reasons, biodiversity conservation in agricultural regions must evolve from a policy based on segregation to one incorporating a wide range of approaches to sustaining native plants and animals in landscapes that are managed mainly for primary production.⁷

Fortunately, some and perhaps many farmers believe that native biodiversity is not something apart or separate from their farm that they can have, or not, as they please.

They believe that biodiversity is essential to a healthy ecosystem, farm, region, country and planet. They argue it is not a question of doing without biodiversity or treating it as an optional extra; it is essential. They contend that, as farmers, they have no alternative but to conserve native biodiversity if they want the best possible landscapes to live, work and relax in. The



Short tussock grassland in a fertilised and over-sown paddock. Tussocks are important for livestock shelter and their tawny colours contribute towards the aesthetic character of the Mackenzie Basin.

presence of this biodiversity is often a key component of their environmental stewardship ethos, and we profile many examples of such farmers in this book.

On the other hand, it is difficult to sustain a conservation argument to protect an isolated tree in a cropping paddock, or a patch of overgrazed degraded grassland that could run four times as many livestock if fertilised and over-sown with introduced pasture species, or generate ten times as much profit if cropped. Nevertheless, the sum of many similar decisions might ultimately contribute to the extinction of a significant proportion of the plants and animals in a region. This paradox raises two fundamental dilemmas about sustaining native biodiversity in agricultural landscapes:

1. An individual organism belonging to a common species or a lone patch of vegetation that is representative of a widespread community may well be dispensable in the greater scheme of things, justifying the destruction of the organism or conversion of the patch to an agricultural use. However, individual decisions, when repeated many times, can have cumulative impacts that are

biologically irreversible. Unfortunately, the science of landscape ecology and conservation biology is weak at predicting critical thresholds of landscape-scale change.⁸

2. If legislation is used to protect every such organism or stand of vegetation, such laws encourage contempt since an individual act by a farmer cannot be demonstrated to be prejudicial in the greater scheme. While laws are respected in civil society, the rigid application of native vegetation clearance regulations can lead to anger and frustration in farming communities, which were often founded in the antipodes by practical people seeking freedom from authority. Despite the importance of legislation and planning rules in ending broadacre vegetation clearance over the past 25 years, such laws discriminate against those who have conserved significant areas of vegetation on their farms, given that the same regulations do not require those who have cleared all their land to put native vegetation back. The irony of laws that penalise those who



Impact of a belah tree on wheat yield near Moree. (Photo: Leah MacKinnon)

have done the ‘right’ thing in the past is not lost on farmers. Justice is also called into question when a system allows wealthy individuals to clear vegetation illegally and absorb the fine as a cost of production, assuming they are caught and successfully prosecuted in the first place.

Reflecting on these issues, we propose five principles critical to sustaining and conserving native biodiversity in agricultural landscapes:

1. **Native biodiversity conservation is important for the innumerable ecosystem services it provides humankind.** Ecosystem services include provisioning services that provide food, fibre, medicines and so on; regulating and supporting services such as flood control, climate regulation, pollination and maintenance of soil and water quality; and cultural services such as aesthetic and recreational values.⁹ While introduced plants and animals are critical to providing the majority of food and fibre in agricultural landscapes, native biodiversity fulfils many important functions in terms of environmental regulation (e.g. soil and water quality), support (e.g. pollination and predator control) and culture (e.g. sense of place) as well as production.
2. **Extinction is forever.** The extinction of species is an irreversible ecological threshold. The finality of extinction is that species cannot be brought back to life. This principle has three corollaries: (1) Because the native biodiversity of a farm, region or country is unique and found nowhere else, it should receive top priority for conservation; (2) Wherever possible and appropriate, native biodiversity should be conserved; and (3) Farmers, indeed land managers everywhere, have a special responsibility for conserving this biodiversity.
3. **Biodiversity conservation issues in agricultural landscapes are a result of the complex interplay between the particular environment, historical management legacies, current commercial objectives, resulting management practices and ecology of the biota concerned.** Given the complexity of factors involved, a wide variety of approaches is required to sustain native biodiversity



Moonbi apple box has a localised distribution on the New England Tablelands of NSW. Conservation of the species is largely dependent on maintaining populations on private grazing land and travelling stock routes.

and solve conservation problems in agricultural landscapes: there is no ‘one size fits all’ solution.

4. **It is not possible to have successful biodiversity conservation in production-dominated landscapes without a viable economy to pay for it, whether the conservation efforts are privately or publicly funded.** There are numerous market failures in relation to the environment where biodiversity loss and pollution have been allowed to be no-one’s responsibility. Greenhouse gas emissions are an obvious example. Since many biodiversity conservation initiatives in farmland are in no-one’s private interest to pursue, someone has to pick up the tab for such causes. In these instances, business and society more generally cannot afford to be green if they are in the red.
5. **For equity reasons, public-good biodiversity conservation should be supported by public funds.** The ecosystem services associated with native biodiversity on private land are often of a

public good nature, including the conservation of native biodiversity for its own sake. It is only fair that conservation be paid for proportionally by all beneficiaries.

One caveat underpins all of the above principles: if farmers and other resource managers reject these principles and their corollaries, then the chances of successful long-term biodiversity conservation in agricultural landscapes are negligible.

In the next few chapters, we outline the key issues to be considered in developing and implementing a wide range of approaches to sustaining native biodiversity in agricultural landscapes. The inherent nature of farming environments, including both the biodiversity that occurs there and the agricultural practices that take place, presents many challenges for conservation. We outline the range of ecological and agricultural issues that are most important to understanding what native

biodiversity occurs in farmland and how it can be secured. We emphasise the fact that given accelerating human transformation of the biosphere, biodiversity will be collateral damage unless many and varied ways are found to accommodate biodiversity in production landscapes in the future. We then present a range of exciting case studies of biodiversity management in agricultural landscapes. The treatment is not exhaustive, our aim being to demonstrate the range of innovative approaches towards integrating biodiversity and farm management, with win-win outcomes for both. Finally, we look to the future and how biodiversity conservation might be achieved in agricultural landscapes. In the integration and synthesis of the inspiring case studies lies the kernel of a new paradigm for nature conservation on farms. We sketch out our perspective of the broad constructs of such a framework in the final chapter of the book.



Farmers working out how to modify a precision crop planter to sow seed of native plants on retired cropping country. (Photo: Leah MacKinnon)

2

WHAT BIODIVERSITY OCCURS IN AGRICULTURAL LANDSCAPES?

This chapter examines the distinction between native and introduced biodiversity, and the patterns that plants and animals exhibit in time and space in response to variation in the natural environment as well as to agricultural development and management. Endemic species peculiar to a particular area are distinguished from widespread or cosmopolitan species found more widely. We also introduce the concept of ecological or biotic communities, that is, the tendency of plants and animals to be distributed in recurring assemblages, called communities, across a region under the same set of environmental conditions (climate, elevation, soil type, etc.). Communities are distinguished by their composition (i.e. the species present) and structure (e.g. grassland, shrubland, woodland or forest), and they exhibit emergent properties such as the numbers of species they contain and their degree of overlap with adjacent communities (i.e. the proportion of species shared in common).



Blackberry was introduced in Australia and New Zealand, and is a noxious or listed weed in many temperate agricultural districts in both countries.

Biodiversity: native and exotic

The plants and animals in a country such as Australia or New Zealand can be classified into two types based on their origins. They are either 'native', occurring naturally in a particular region, or 'introduced' by humans, intentionally or accidentally. Native species have generally evolved *in situ*, often over long periods of time. The evolution of marsupials and diversification of eucalypts in Australia is a classic example of this. Similar examples of *in situ* evolution can be found in New Zealand, especially among alpine plants such as buttercups, hebes, spaniards and mat daisies which have undergone extensive speciation during the Quaternary glaciations, and in animal groups such as lizards, wetas (large insects related to grasshoppers) and land snails. Species introduced to Australia and New Zealand by Europeans, on the other hand, are recent arrivals and haven't had an evolutionary period of co-adjustment with the native biota.



Canterbury mudfish, an endemic freshwater fish, confined to lowland streams and wetlands in Canterbury.
(Photo: Angus McIntosh)

The concepts of native and endemic are related. Endemism refers to the natural occurrence of an organism in a particular area. Almost a quarter of vascular plant genera and 92% of species in Australia are found nowhere else and are therefore Australian endemics.¹⁰ Half of the vascular plant species in south-western Australia and 43% in the Wet Tropics World Heritage Area in north-eastern Queensland are endemic to those regions. In the case of the Wet Tropics, 13 of the world's 19 most primitive flowering plant families are found nowhere else. In terms of animals, 87% of native mammal species, 45% of birds, 93% of reptiles and 94% of amphibian species are endemic to Australia. Similar patterns occur in New Zealand, where 57% of the land and freshwater birds, 84% of angiosperms, 90% of insects and spiders, and all frogs and reptiles are endemic.¹¹ However, some distinctive species, while native, are not endemic – the great white egret or white heron is native to both Australia and New Zealand, but is not endemic to either as it occurs throughout much of the world. All native biota in a region should be conserved, because local plants and animals are likely to be adapted to local conditions and be genetically distinct from populations of the same species in other regions. However, it is particularly important to conserve the native plants and animals that are endemic or unique to a region or country, as their loss translates into global extinctions.

There is, of course, a grey area – the plants and animals introduced by indigenous peoples in both countries. Asian seafarers are thought to have introduced the dingo into

Australia 3500–4000 years ago¹² and Polynesian settlers the Pacific rat (kiore) and dog (kuri) into New Zealand about 750 years ago.¹³ Are these native or introduced? There is no easy answer, but a possible distinction can be made based on the impact of these species in the native ecosystems of which they are now part. Dingoes were thought to have replaced the thylacine (Tasmanian tiger) throughout mainland Australia within 500–1000 years of their arrival from Asia, although humans also probably played a role in thylacine decline.¹⁴ Other elements of the ecosystems in which dingoes now occur are adjusted or 'harmonised' to their presence. Although dingoes hunt and kill native fauna, particularly large kangaroos, dingoes and their native prey coexist.¹⁵ Thus, dingoes are regarded as native despite their human-assisted origins in Australia. In New Zealand the situation is quite different. While kuri have been lost through interbreeding with European dogs, kiore still have a substantial impact on native birds, reptiles and invertebrates in the places where they persist, although they have now been largely lost from the main islands due to competition with Norway and black rats. Kiore are thus regarded as introduced.

Another grey area is the set of plants and animals that have recently invaded Australia and New Zealand without human assistance. Cattle egrets arrived and expanded in Australia during the 20th century, probably from Asia,¹⁶ and welcome swallows arrived in New Zealand from Australia around the time of European colonisation.¹⁷ Humans did not introduce them, but they did introduce the cattle herds and built the structures that facilitated the survival of cattle egrets and swallows in Australia and New Zealand. Nevertheless, these species are regarded as native, having arrived under their own steam.

More recent human introductions such as stoats, common brushtail possums and Norway rats in New Zealand or rabbits, foxes and camels in Australia have a detrimental effect on native biota, continuing to cause local declines and extinctions of native plants and animals in the respective countries. Thus, while biota brought in by people thousands of years ago and those species that have arrived naturally in more recent times can be regarded as native if the natural ecosystems in which they occur are harmonised to their presence, the plants and animals introduced by people in the last few hundred years are clearly not native.



The Western Australian Christmas tree is a root-parasitic mistletoe (Loranthaceae) endemic to south-western Australia.

Having defined the two major components of biodiversity, native and introduced, each can be subdivided into several categories in terms of their response to the environmental changes consequent upon settlement and development. Among the native biota, several categories of response are evident:

1. **Global extinctions.** Some species that were endemic to Australia or New Zealand could not cope with the impact of human settlement and are now extinct. In New Zealand, the c.12 species of moa disappeared within 200 years of the arrival of indigenous people, while huia (a wattled crow), laughing owl, piopio (native thrush) and the bush wren have gone extinct in the last 150 years because of habitat loss and predation.¹⁸ In Australia, the Kangaroo Island emu, paradise parrot and about 20 species of mammal in the critical weight range, 35–5500 g, have disappeared since the arrival of Europeans (the mammals largely as a result of fox and possibly cat predation, with sheep pastoralism implicated as well).¹⁹ Further back in prehistory, it is probable that the arrival of the first people in Australia gave rise to the extinction of the megafauna (diprotodons, giant kangaroos, giant emus, etc.), 45 000–50 000 years ago.²⁰
2. **Local or regional extinctions.** Some native species were unable to cope with human settlement where the impacts and scale of change were most severe. Thus, in Australia, many extant species of small to medium-weight mammal are now confined to offshore islands where foxes are absent and pastoral impacts slight. Similarly, in New Zealand, the tuatara and a range of birds including the kakapo (parrot) and little spotted kiwi are confined to offshore islands as a result of predation by introduced animals (stoats, rats, etc.) on the main islands.²¹ In mainland Australia, bush stone-curlew, bustards and dingoes have gone from most of the southern two-thirds of the continent as a result of fox predation or human persecution, but persist in comparatively good numbers in northern Australia.
3. **Decreasers.** Many native species of plant and animal have specific habitat requirements associated with the soils and landforms, native vegetation or aquatic ecosystems that occurred prior to human settlement.



The paradise parrot, a southern-central Queensland endemic, is globally extinct.

In regions where these habitats have been heavily impacted or destroyed (e.g. the conversion of forest or woodland to pasture or crop), decreaser species have suffered declines in their distribution and abundance in parallel with habitat destruction, but persist in low numbers. In New Zealand, this has been exacerbated by the impacts of predation.²² In the south-eastern Australian wheat–sheep zone, a suite of woodland-dependent birds that were commonly recorded by ornithologists in the first half of the 20th century have become less common over the past 50 years as native vegetation has been cleared and the wheatbelt expanded.²³



Dingoes are now locally extinct across much of the settled part of the southern half of Australia as a result of human persecution. (Photo: Guy Ballard)

What is significant about the trend in the abundance of decreaseers is that even where their habitat remains in a more or less intact state, they are less abundant or sometimes no longer occur. Today's decreaseers may well be tomorrow's regional extinctions, or worse. Plants and animals that have seriously declined in geographic range or abundance are described as threatened. Threatened communities are recurring assemblages of plants and animals that have suffered a marked decline in area, condition (e.g. loss of species, habitat degradation) or both. Threatened species, plants and animals that are naturally rare and therefore vulnerable to extinction, and the communities they form, are regarded as species or communities of conservation significance and concern, and are listed at state and national levels.²⁴

4. **Stayers.** Some species with particular habitat requirements continue to occur in remnant vegetation or wetlands, wherever suitable habitat remains. Although stayers may have suffered regional declines in distribution and abundance as a result of habitat destruction, they continue to persist in much the same abundance in remaining areas of habitat. The dominant trees, shrubs and grasses in remnant vegetation might be examples, provided populations are reproducing and



The shrubby tororaro, endemic to the south-eastern corner of North Island and the north-eastern South Island, is threatened by a lack of regeneration due to competition from exotic grasses, browsing animals and trampling. As a result it is ranked as nationally Vulnerable.

replacing themselves. In New Zealand a number of small forest birds including fantail, grey warbler and silvereye persist even in highly modified areas. Bellbirds (honeyeater) appear to be slowly increasing in abundance after earlier declines, perhaps because of increasing resource availability as woody vegetation (native and exotic) expands across rural landscapes.

5. **Increasesers.** Some native species have done very well out of European settlement. Magpies, crows and ravens in southern Australian farming districts and the swamp harrier, pukeko (swampphen) and paradise shelduck in New Zealand farmscapes are some of the winners from agricultural development. These species have been able to increase in numbers at a local scale, expanding out of open habitats such as wetlands and rivers into adjacent agricultural habitats in the New Zealand case.
6. **Native invaders.** Another set of winners from farming are the native plants and animals that were not originally present in an area at the time of settlement, but have since invaded. As the forests, woodlands and mallee of southern Australia were cleared, and cereal crops and pastures established, farmland became attractive for some arid interior species, such as galahs and little corellas (both cockatoos), and crested pigeons. These species expanded out of the arid zone into wetter districts as agricultural land was developed in the early part of the 20th century and are now abundant in farming districts throughout southern mainland Australia. Both increaseers and native invaders can become agricultural pests, owing to their abundance and predilection for food resources associated with farming, such as grain (parrots and cockatoos), fruit (rosellas, lorikeets, silvereyes and honeyeaters), pasture (large kangaroos, pukeko and paradise shelduck) or livestock (wedge-tailed eagles, crows and ravens).

Corresponding sets of winners and losers are evident among the biota introduced by people:

1. **Introduced invaders.** An increasing number of introduced species have been highly successful in invading predominantly native habitats, displacing



Magpies have increased across much of Australia, benefiting from European settlement, and are an introduced invader in New Zealand.

native species, dominating vegetation layers or changing faunal communities. Invasive perennial grasses from Africa and South America, such as African lovegrass, Coolatai grass, Chilean needle grass and whisky grass, are spreading rapidly through northern NSW, not only along roadsides but into grazed pastures and areas of native vegetation. Buffel grass is expanding similarly throughout inland northern and eastern Australia. In New Zealand, European hawkweeds are rapidly invading tussock grasslands, while a number of climbing plants (banana passion vine, old man's beard, Chilean flame creeper) increasingly threaten forest remnants throughout the country. Rabbits have had a major impact on native ecosystems in Australia and New Zealand. In Australia, their impact on the recruitment of slow-growing, long-lived shrubs and trees may result in many extinctions in arid and temperate areas over the next few hundred years. In New Zealand, rodents and mustelids (stoats, weasels, ferrets) have had a dramatic impact on reptiles and birds, driving several species to extinction and others to the point where they only survive on remote offshore islands or in intensively managed areas. European foxes in Australia have had a similar impact on small to medium weight range mammals and some ground-nesting birds. Brushtail possums and ungulates (deer and goats) have caused substantial and



Galahs (native invaders) have expanded from their arid zone range into the wheat-sheep belt and higher rainfall districts in southern and eastern Australia in historical times as a result of vegetation clearance. (Photo: Lydia Paton)

possibly irreversible long-term changes in forest composition in New Zealand.

2. **Infiltrators.** Another set of introduced species has spread widely into largely natural areas and native vegetation, but impacts on other species are unclear. The two species of flatweed or cats-ear (European daisy) are among the most abundant plants in native pastures in northern temperate NSW, but it is unclear whether they are of any consequence other than simply occupying space. Wall lettuce, a small daisy, is widely distributed through New Zealand beech forests but, again, its consequences seem negligible. In New Zealand, small European granivorous and insectivorous birds such as



Cats-ear, an example of an infiltrator.



Goats are an example of an introduced invader unlike cattle, which are primarily stay-at-homes. (Left photo: Lynn Pedler)

chaffinch, greenfinch and redpoll occur widely in native habitats; their ecological consequences are little understood and they are also probably best regarded as infiltrators. In fact the majority of invasive species that have become naturalised (i.e. self-sustaining in the wild) are infiltrators. However, this group of introduced species includes a subset that will, without doubt, become invasive in the future. These have been referred to as ‘sleepers’,²⁵ species that presently occur in low numbers but have the potential to become significant invaders in the future. Unfortunately, the factors that trigger the change from sleeper to invader are poorly understood and difficult to predict.²⁶

3. **Stay-at-homes.** Some introduced species of plant and animal confine themselves to the areas in which they are introduced, without becoming naturalised. In other words, they do not establish self-perpetuating populations in the wild. Chickens, for example, tend not to ‘go feral’, unlike pigs, goats and horses in various parts of Australia and New Zealand. These species may well, however, have an impact on native biodiversity in farmland. The selective grazing of sheep has had a major impact on vegetation in both arid Australian rangeland and the temperate grasslands and grassy woodlands of south-eastern Australia. In arid Australia, the distribution of the sheep rangelands coincides with the regions in which most small to medium

weight range mammal extinctions have occurred.

In temperate south-eastern Australia, many species of grazing-sensitive forb (e.g. rare daisies, lilies and orchids) are now largely confined to small reserves, such as cemeteries, where by chance sheep have been excluded since European settlement.

While introduced species are best known for their negative impacts on native biodiversity, introduced species including some invaders can also play positive roles. For example, in New Zealand, the invasive brushtail possum disperses the seeds of some native plants²⁷ while the European invasive shrub, gorse, can act as a nurse plant facilitating native forest establishment in abandoned exotic pastures.²⁸ Many introduced plants, invaders, infiltrators and stay-at-homes, also provide key food resources for native animals. In the Mount Lofty Ranges of South Australia, diamond, beautiful and red-browed firetails (finches) make use of a wide variety of introduced grasses and forbs.²⁹ In New Zealand, giant weta have been recorded living in gorse shrubland,³⁰ while bellbirds (honeyeaters) supplement their diet in farmland with nectar from planted eucalypts and acacias.

Biodiversity patterns

The biodiversity that occurs in any one place, for example in a field or a patch of forest, is the product of a range of factors selecting from among the regional pool of plant and animal species. These factors include both the attributes of the environment that determine

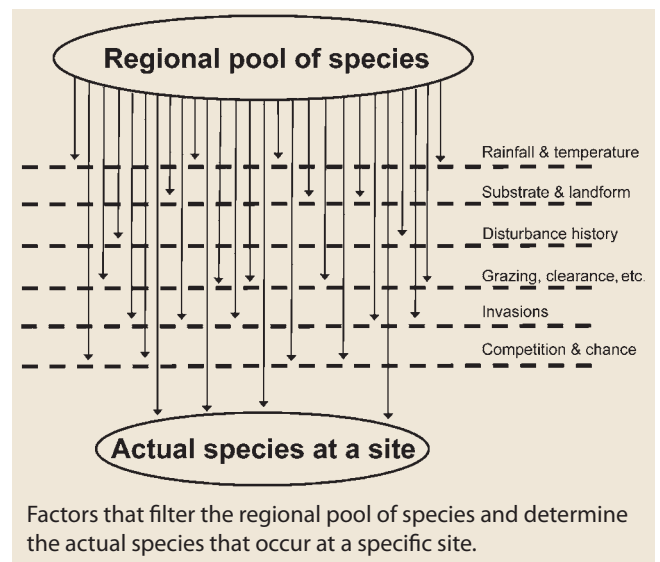


The remnant grassy white box woodland in Currububula Cemetery, NSW, is one of the few sites in south-eastern Australia retaining its pre-European understorey of kangaroo grass, wild sorghum, tussock poa and a range of grazing-sensitive wildflowers, due to the exclusion of livestock early in European settlement.

the original (pre-agricultural) biodiversity (e.g. factors such as rainfall, temperature, soil fertility and natural disturbance history) and the direct and indirect effects of human activities (e.g. vegetation clearance and cultivation, fertiliser input, grazing, hunting, introduction of exotic plants and animals, and species extinctions). Together with ‘chance’ (i.e. the fact that a particular species arrived by chance at a site, established and persisted), these factors dictate the actual species present. These environmental and management factors are filters that sift the set of plants and animals that occur at any given site from the regional pool of species. To understand the patterns of biodiversity that occur in agricultural landscapes today, it is important to understand the factors that filter species composition.

Filters of species composition operate across different spatial and temporal scales. At the largest spatial and temporal scales (global and millennia), species composition has been shaped by the history of the Earth itself and in particular the movement of continents and the evolution of flora and fauna. The absence of pines, oaks and other northern hemisphere trees in Australia

and New Zealand reflects differences in the evolutionary history of different parts of the world, while the abundance of marsupial mammals in Australia and the absence of snakes and native terrestrial mammals in New Zealand is a product of the separate geological and evolutionary histories of each country. At smaller spatial and temporal scales, the climate and sea-level fluctuations associated



with the Quaternary glaciations over the last 2.6 million years have further shaped the modern biota of Australia and New Zealand. Land bridges between Australia and New Guinea and some near islands of Indonesia during periods of low sea levels facilitated species transfers, while in New Zealand several species including coconuts and giant penguins were eliminated during cold glacial periods.

At regional scales, gradients in moisture and temperature influence broad distribution patterns, for example with altitude or distance from the coast. In South Australia, on fertile, well-drained soils, peppermint box woodland once occurred across the Adelaide coastal plain (elevation of Adelaide 40 m a.s.l., mean annual rainfall 530 mm, mean annual temperature 17°C). It graded into grey box woodland as the plains sloped upwards to the foothills of the Mount Lofty Ranges, giving way to tall open-forest of blue gum, river red gum, candlebark gum and white gum in the cooler, well-watered valleys around Mount Lofty (Stirling Post

Office: 500 m a.s.l., 1110 mm, 13°C). Tall open-forest graded into pink gum and sheoak (*casuarina*) low open woodland or hard mat-rush grassland on the drier ranges along the eastern fall (Rockleigh: 320 m a.s.l., 520 mm, 20°C), and mallee low woodland and scrub on the plains towards the River Murray (Murray Bridge: 35 m a.s.l., 350 mm, 23°C). Similar gradients can be found in New Zealand where rimu and kahikatea-dominated temperate lowland rainforest (<300 m a.s.l., mean annual rainfall 2500–5000 mm) gives way to mixed conifer–angiosperm forest at mid elevations (200–800 m a.s.l., >3000 mm) and subalpine rainforests and shrublands at higher elevations (800–1300 m a.s.l., >5000 mm). Alpine grasslands and herb fields occur above the upper limit of woody plants (>1300 m a.s.l.). To the east of the ranges, alpine grasslands are replaced with decreasing elevation by temperate beech forests (<1400 m a.s.l., 800–2000 mm), and woodland and shrubland in the driest inter-montane basins (500–700 m a.s.l., <800 mm).



Peppermint box (upper left) and grey box woodland (lower left) on better soils on the Adelaide Plains, giving way to tall open-forest of South Australian blue gum (right) in valleys in the Mt Lofty Ranges due to higher rainfall and cooler temperatures. (Photos: Lydia and David Paton)



Kahikatea (left) dominates on fertile alluvial surfaces while rimu (right) dominates on infertile glacial outwash surfaces in south Westland lowland rainforests.

At smaller spatial and temporal scales, variations in land form and substrate (e.g. slope, aspect, soil type) drive distribution patterns. In the Mount Lofty Ranges, river red gum gallery forest along drainage lines grades into blue gum and manna gum open-forest on the adjacent flats and valley floors. These forests grade into stringybark and pink gum open-forest and woodland on the surrounding hills of metamorphosed sediment and quartzite, with stands of sheoak atop rocky hilltops. In lowland western South Island, conifers dominate the forests on level sites, with kahikatea on fertile silty alluvial soils, matai and totara on fertile stony alluvial soils, and rimu on poorly drained and infertile glacial outwash surfaces. Mixed conifer–angiosperm forests dominate the adjacent hillslopes. Animal distributions typically follow these vegetation patterns, although the seasonal availability of particular food resources in different vegetation types can also be important.

Disturbances such as fire, windthrow or outbreaks of defoliating insects also play a key role in shaping species

composition across a range of scales. For example, fire can kill the young seedlings of native shrubs such as budda, turpentine and hopbush (‘woody weeds’) in grassy poplar box woodland on the Cobar pediplain in western NSW.³¹ Where fire doesn’t remove woody weed seedlings shortly after a major germination and establishment event, the grassy woodland structure can shift to a dense shrub-woodland, losing the grassy understorey due to the competition from mature shrubs and overgrazing. In montane New Zealand cool temperate rainforests, natural outbreaks of the defoliating insect *Inglisia* triggered by drought events stressing the red beech forest canopy result in red beech dieback, allowing rapid growth and canopy occupation by silver beech. The heterogeneity that results from disturbances allows a diversity of plants and animals to coexist within the same broad habitat type by exploiting the different resources available at different stages, post-disturbance. The absence of a species or group of species from a site may simply reflect the time since



Uninvaded grassy poplar box woodland (left) and woodland invaded by unpalatable shrubs and regenerating pine (right), Cobar pediplain, NSW.

the last disturbance, rather than underlying physical factors such as soil or aspect. Disturbances can also interact with the abiotic environment in shaping species distributions. For example, in the escarpment gorge country of northern NSW, the distribution of dry rainforest and grassy woodland reflects a combination of site factors and disturbance history: dry rainforest is restricted to south and east-facing gullies and scree slopes, which are moister and do not carry fire. In Australia, disturbance effects may be even more complex as a result of 45 000 years or more of human occupation and Aboriginal use of fire, although the amount and nature of any resulting vegetation change is debated.

The underlying natural distribution patterns of plants and animals have been further modified by more recent human activity, especially in the 150–250 years of European settlement of New Zealand and Australia. Some modifications are direct and their impacts obvious, such as vegetation clearance and replacement with crops, sown pastures and livestock (e.g. dairy cows grazing an alluvial floodplain of introduced grass–clover pastures that would have supported dense kahikatea forest in New Zealand, or wheat and cotton replacing grassy woodlands in inland eastern Australia). However, many changes are more subtle and their consequences less apparent. Examples include changes to soils through fertiliser input or water abstraction, or shifts in composition of native vegetation as a result of grazing. Invasive species

have further altered the distribution and abundance of native species, even in habitats that have not been directly impacted by European settlement, to the extent that today most farmland habitats include mixtures of native and exotic species.

All of these factors, natural and anthropogenic, give rise to a tremendous amount of spatial heterogeneity in biodiversity across a wide range of scales, from a single point, to the scale of a paddock or farm, a region or a whole country. This heterogeneity is critical for species as it affects the way that individuals of the same species are arranged (e.g. in scattered patches or populations separated from others), the way species move around a landscape, and the way that activities at landscape (e.g. farming practices) and larger scales (e.g. global climate change) affect biodiversity. There is also variation in biodiversity through time, at a single point in space as one group of species replaces another, and at larger scales as different suites of species replace each other in response to broad environmental and anthropogenic conditions.

An appreciation of the factors influencing species' distribution patterns is critical for understanding the biodiversity that occurs in agricultural landscapes. The predominance of agriculture in the most productive landscapes means that some species and communities are more likely to be associated with agriculture than others, and it is these species that are disproportionately affected by agricultural practices. For example, in New



Windthrow is a common natural disturbance in New Zealand beech forests.

Zealand, while more than 30% of the land area is held in the public conservation estate, only 18% of the land below 500 m is protected in this way, with most of the 82% of non-protected land dominated by pastoral and plantation forest ecosystems.³² Furthermore, owing to the influences that dictate species distribution patterns, the total distribution of many species lies entirely within agricultural landscapes. Globally, the primary distribution of more than half of all species lies



Illegal clearing of native vegetation in Australia remains a threat to biodiversity. (Photo: Chris Nadolny)

outside protected areas within primarily agricultural landscapes.³³ Because of the effects of human activities in farming districts, many of the native species that occur there are under threat. For example, 20% of New Zealand's threatened vascular plants (i.e. flowering plants, conifers and ferns) are restricted to private land (primarily agricultural land). A further 60%, although present on both protected and non-protected lands, have their largest populations on private land. In Australia, more vascular plants are threatened with extinction by agriculture, especially vegetation clearance, cultivation and grazing, than any other factor.³⁴ Prior to the cessation of broadacre vegetation clearance in Queensland and New South Wales, native vegetation clearance was regarded as the single most significant threat to terrestrial biodiversity.

Communities and turnover

Species occurring together in space and time are referred to as a community. Communities vary in structure and composition due to differences in the factors discussed above, such as climate and soil type. Within a region, there can be a reasonable degree of predictability about community composition and structure, such that the



Diverse ecological patterns with high species turnover resulting from a complex interplay between altitude, topography and underlying geology, Matiri Range, north-western South Island.



The monotonous pattern of gilgais (slight depressions) containing bladder saltbush scattered across a bindii-dominated stony tableland in central South Australia.

same community with its characteristic assemblage of species and structure occurs repeatedly in the same topographic position on the same soils across the landscape. In the Western Australian wheatbelt, salmon gum woodlands occur on mid slopes. Salmon gum is replaced by gimlet woodlands in the valley bottoms and diverse shrubland communities on higher parts of the landscape, across an area of 16 million ha.

Turnover refers to the number or proportion of species that are gained and lost in moving from one point to another across a farm, region or continent, reflecting the diversity of different communities present. High species turnover is usually driven by a diverse physical environment resulting in many different communities in the same area (e.g. the geologically diverse mountains of Kahurangi National Park in the north-western South Island), while areas with low turnover are usually characterised by a smaller number of communities reflecting a more uniform abiotic environment (e.g. the Nullarbor Plain of southern Australia). In regions with high species turnover, it is important to retain a denser array of natural and semi-natural habitats to conserve the diversity found in such areas than in a region with low turnover, where fewer habitat patches support most or all of the biota.

Conclusions

Agricultural landscapes can support a significant amount of biodiversity; often more than in undeveloped regions

because of the mingling of native and introduced biota and the opportunities for a wider range of native species offered by farmland mixed with natural landscapes. Some of the native biota in each agricultural region are unique to that place, and because of the history of human impact, some of the native plants and animals may be threatened. It is also clear that the amount of native biodiversity that occurs in farmland is variable, reflecting both the underlying influences of pre-agricultural species distribution patterns, and the history of human activities. A variety of native plants and animals occurs in farming districts, including species of conservation significance. ‘Stayers’ are quite happy in the farm environment provided management does not change. In fact, changing farm management by requiring the habitat be ‘protected’ from agricultural management (e.g. by putting a fence around it and excluding livestock) can endanger some plant or animal species. In their book, *People, Sheep and Nature Conservation: The Tasmanian Experience*,³⁵ Jamie Kirkpatrick and Kerry Bridle warn ‘if it ain’t broke, don’t fix it.’ They cite several examples where rare native plants are maintained in native grassy vegetation by commercial sheep grazing in Tasmania. However, the situation across most of rural Australia and New Zealand is that only a fraction of the original biota can survive in intensively developed agricultural landscapes, and various on- and off-farm conservation strategies are therefore required to safeguard all of the regional biota.

3

ACCIDENTS OF HISTORY, FARMING AND THE IMPACT ON BIODIVERSITY

The significance of prehistory

People have had a long period of coevolution with plants and animals in those parts of the world where humans evolved. Our ancestors originated in Africa more than 4 million years ago.³⁶ Early humans colonised Eurasia up to 2 million years ago and Neanderthal-like people occurred in western Europe, the eastern Mediterranean and India as early as 600 000 years ago.³⁷ By contrast, modern humans only spread from Africa into Eurasia and elsewhere in the past 100 000 years or so.

The spread of modern humans was decisive for most of the world's megafauna (i.e. large terrestrial vertebrates of open habitats, greater than about 100 kg in body mass, and with low reproductive rates). Although most large mammals in Africa (elephants, rhinoceros, hippopotamus, etc.) survived to the present day, most of the megafauna encountered by modern humans in Australia, the Americas and New Zealand (e.g. ground sloth, diprotodon and moa) promptly became extinct. One reason suggested for this is that the African megafauna adapted to predatory humans, evolving coping strategies as modern humans developed increasingly sophisticated hunting skills in the past few hundred thousand years.³⁸ By contrast, the large animals of other land masses were unprepared for the arrival of modern humans with their well-honed hunting skills at different times in the past 50 000 years or so, with catastrophic consequences for the animals concerned.³⁹

Understanding the coevolution of people and biota in Eurasia is informative in understanding the behaviour of plants and animals introduced into Australia and New Zealand by Europeans. Neanderthals occupied Eurasia for hundreds of thousands of years prior to the arrival

of modern humans, at a time when ice sheets waxed and waned across northern Eurasia in repeated cycles of glaciation and warming. Northern hemisphere plant and animal distributions underwent repeated migrations as a result, with sorting and reshuffling of species assemblages in association with human occupation and the harvest of wild plants and hunting.⁴⁰ The initial cultivation of early crops in the Near East, 10 000–13 000 years ago,⁴¹ and the simultaneous domestication of livestock, represented simply a new chapter in the long and evolving relationship between people and the Eurasian biota. Not surprisingly, a range of commensal plants and animals coevolved with humans, their domesticates and management practices (permanent settlement, plant gathering, hunting, herding, burning, forest clearance and tillage), benefiting from the human lifestyle.

One issue of particular significance for Australia and New Zealand is the coevolution of ungulate animals and vegetation in the northern hemisphere and Africa over the past 20 million years or so.⁴² Ungulates evolved long lower limbs in order to run faster, such that they now walk on just their hardened toes (i.e. hooves). This results in ungulates having higher impact forces on the ground compared to large but soft-footed organisms, such as herbivorous marsupials (e.g. kangaroos) and large flightless birds (e.g. moas). Some ungulate groups such as cattle, sheep and deer have also evolved a series of stomachs to increase the digestive efficiency of cellulosic and lignified plant tissues. Consequently, the plants with which ungulates coevolved have developed a wide array of adaptive tolerances and defences to cope with heavy grazing and browsing, as well as trampling. Examples include structural adaptations (e.g. lignins and thorns) and secondary compounds (e.g. tannins and phenolics)

that reduce plant palatability.⁴³ That ungulates were domesticated by early agriculturalists in the Near East is particularly relevant to Australia and New Zealand.

Like their northern hemisphere counterparts, southern floras evolved with a range of herbivorous animals. The New Zealand flora evolved with grazing or browsing birds (moas, takahe) and insects (wetas). Australian vegetation coevolved with marsupial grazers and browsers, including giant kangaroos and diprotodons. Australian and New Zealand vegetation and landforms were, however, ill-prepared for large numbers of cattle and sheep, or the establishment over large areas of feral ungulate populations including goats, camels, horses and buffalos in Australia and goats, deer, chamois and thar in New Zealand. The impact of large numbers of ungulates in Australia and New Zealand was severe in arid, temperate and alpine zones,⁴⁴ with widespread damage to soils, erosion and loss of palatable species. Soil compaction in grazed woodlands remains higher than in ungrazed woodlands,⁴⁵ and many farmers avoid grazing their cultivation country on alluvial floodplains because of the impact of soil compaction on subsequent crop yields, despite the benefits of crop–pasture rotations.

This brief survey of human coevolution with African and northern hemisphere plants and animals provides a useful insight into the different types of landscape associated with modern agriculture. Cultural landscapes developed in Eurasia over the past several hundred thousand years associated with hunter–gatherer

occupation, and in the past 10 000 years with the farming and livestock domestication of modern humans. These cultural landscapes are characterised by plants, animals and soil types that have been moulded and shaped by human activity and ungulate grazing, browsing and trampling. The nature and impact of the vegetation changes associated with prehistoric human impact are well documented in both Europe and North America.⁴⁶ By contrast, the New Zealand grasslands and forests encountered by human settlers were a frontier landscape, highly susceptible to the burning practices of Maori settlers and the subsequent burning, ungulate grazing and cultivation of European settlers. New Zealand plants are not fire-adapted and the fires associated with Maori and European settlement resulted in major changes in vegetation cover. Subsequent grazing by both domestic and wild ungulates (sheep, cattle, goats, deer, etc.) devastated forest understoreys and resulted in rapid loss of palatable species from both forests and grasslands, vegetation types that were only adapted to avian grazers such as moa⁴⁷.

Australian ecosystems represent a half-way house between cultural and frontier landscapes. Due to increasing aridity from the mid to late Tertiary, most Australian vegetation types were already fire-adapted when the first people arrived, with a few notable exceptions, such as rainforest, chenopod shrubland and brigalow. It is debatable whether the burning practices of the first human inhabitants of Australia caused widespread vegetation change,⁴⁸ but the use of



Eastern grey kangaroos grazing a fertilised temperate pasture.



Cloven-hoofed sheep have a higher ground impact than the soft-footed animals such as kangaroos and moa that preceded them in Australasian grasslands.



Forest understorey heavily grazed by cattle and sheep with no shrub or ground vegetation remaining, North Canterbury.

fire by Aboriginal people would have only increased the resilience of fire-adapted vegetation types by the time of European colonisation. Most major vegetation formations were not readily susceptible to transformation by European burning since most are dependent on recurrent fire.⁴⁹ On the other hand, overgrazing by sheep and cattle represented a novel and sometimes overwhelming challenge, transforming shrublands to grasslands or ephemeral herblands, grasslands to shrublands or woodlands, and grassy woodlands to shrub woodlands, sometimes in conjunction with the removal of fire and the introduction of exotic plants.

The origins and age of agricultural development in the northern hemisphere assume significance in relation to the impacts of Western agriculture in frontier landscapes. The farming of cereals 10 000–13 000 years ago in the Near East soon extended around the Mediterranean rim, supplanting hunting and gathering. Cattle and sheep were domesticated about the same time in the eastern Mediterranean, and pasture plants were sought for domestication from among the grasses and legumes associated with livestock grazing in Europe, North Africa and south-west Asia. Not surprisingly,



Overgrazed grassy poplar box woodland in western NSW during drought.

Eurasia and North Africa are the geographical origin of most of the common species sown in temperate and Mediterranean-climate pastures in southern and eastern Australia and New Zealand today. Tropical and subtropical pasture grasses and legumes have been sourced more widely from sub-Saharan Africa, Asia and the Americas.



The yellow-flowered European broom was brought to New Zealand as an ornamental plant, but is now widespread through rural areas on disturbed or marginal farmland.

Weeds associated with cultivation in the Near East have had at least 10 000 years to adapt to permanent human settlement and the disturbance associated with tillage, irrigation and soil enrichment with manure. Weedy plants associated with early farming in the Far East, Mesoamerica and North America had almost as long to adapt to the disturbances associated with human settlement and tillage. Prior to humans sowing crops and domesticating animals, modern people were already living a sedentary lifestyle and harvesting the wild forms of early crops, so weeds associated with various forms of human disturbance including weeding, reaping and village or cave life evolved over a longer period. Of greater antiquity still is the period of coevolution and adaptation of forage plants and weeds in the northern hemisphere and Africa with ungulate herds, a period of 30–50 million years. Thus when colonists brought their farming systems and livestock

to the frontier landscapes of Australia and New Zealand from the late 1700s, they brought by design or chance, a wide range of forage species and commensal weeds of cultivation and pasture that were adapted to agricultural soil disturbance, ungulate grazing and livestock management. European farming techniques had to be modified to suit antipodean conditions, but it is no surprise that the food and fibre-producing plants and animals introduced to Australia and New Zealand were co-adapted with each other. Many of the weeds of agriculture in Australia and New Zealand are weeds in similar situations in their countries of origin in the northern hemisphere, South America or southern Africa. Some have also become major environmental weeds more generally in their new homes in southern lands, especially in the absence of ungulate grazing, which is an important check on their abundance in their home ranges.

A spectrum of farming systems

Farming systems in Australia and New Zealand can be characterised in terms of three key attributes of the dominant plant species: longevity (annual or perennial), growth form (tree, shrub, grass or forb) and origin (native or introduced), as well as the source of water used for production (rainfed or irrigated).

The type of farming system is a key influence on the biodiversity associated with agriculture. Some agriculture such as extensive dryland and irrigated cropping results in the removal of all of the aboveground native biodiversity from production areas, even entire farmscapes. Conservative arid rangeland management, on the other hand, is probably compatible with the conservation of most of the extant native biodiversity. These differences between farming systems are due to differences in associated land and water-use practices.

Grazing systems

Rangeland grazing, in its simplest form, involves depasturing livestock on native vegetation. If the stocking rate is low enough, the distance between water points large enough, and the period of the year in which grazing occurs limited enough, even the most fragile soil types remain undamaged over most of the range and sensitive grazing-intolerant plants survive in rarely or never grazed areas.⁵⁰ In some range types, it is difficult to find significant grazing impacts in terms of loss of plant species due to grazing in commercially grazed grasslands under conservative management.⁵¹ In other environments, the stocking rates and grazing management associated with commercial enterprises can cause significant change in grassland composition, even without fertiliser or sowing of introduced pasture seed.⁵² Sheep grazing in the box–gum grassy woodlands of south-

Farming systems classified according to the longevity, growth form and origins of the dominant plant species, and source of water for production.

Longevity	Origin	Growth form	Water source	Examples
Annual	Native	Grass	Dryland	Degraded rangeland
Annual	Exotic	Grass	Dryland	Cereals, sorghum
Annual	Exotic	Grass	Irrigated	Irrigated cereals (e.g. wheat, rice), sugar
Annual	Exotic	Forb*	Dryland	Canola, rape, kale, turnip, sunflower, peanuts, vegetables, potatoes
Annual	Exotic	Forb*	Irrigated	Irrigated clover, legumes (chick peas, faba beans), vegetables, strawberries
Perennial	Native	Grass	Dryland	Native pasture (natural, volunteer and sown)
Perennial	Native	Shrub/vine	Dryland	Saltbush, tea tree oil, pepperbush plantings
Perennial	Native	Tree	Dryland	Eucalypt and totara farm forestry, macadamia orchards
Perennial	Native	Tree	Irrigated	Irrigated tree plantations (e.g. sewage effluent, high-value eucalypt and other essential oil plantations)
Perennial	Exotic	Grass	Dryland	Sown pasture (including grass–clover pastures)
Perennial	Exotic	Grass	Irrigated	Grass–clover pastures
Perennial	Exotic	Forb*	Dryland	Dryland lucerne
Perennial	Exotic	Forb*	Irrigated	Irrigated lucerne
Perennial	Exotic	Shrub/vine	Dryland	Lavender, tea, coffee, grapes, tagasaste alley farming, kiwifruit
Perennial	Exotic	Shrub/vine	Irrigated	Irrigated grapes, stone fruits, kiwifruit
Perennial	Exotic	Tree	Dryland	Farm forestry (conifers, eucalypts in NZ), horticulture (e.g. citrus)
Perennial	Exotic	Tree	Irrigated	Irrigated horticulture (e.g. citrus, pecans, bananas)

* A forb is a broadleaved (non-grass-like) herb.



Irrigated farmland in the Namoi Valley, north-west NSW. The grey, brown and light green rectangles are cropping paddocks, the dark green areas are remnant areas of native grassland and woodland in paddocks, on travelling stock routes and along rivers, and the blue areas are water storages. (SPOT image courtesy of Rhiannon Smith and the NSW government)



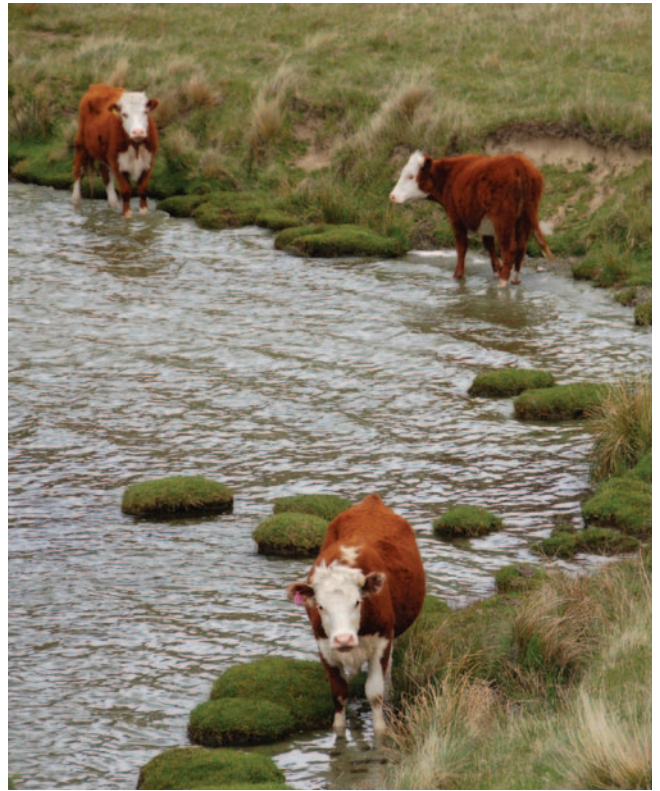
Kangaroo grass, wild sorghum and tussock poa-dominated grassy vegetation across the Northern Tablelands of NSW prior to the introduction of livestock.

eastern mainland Australia is associated with the loss of summer-active dominant grasses such as kangaroo grass. They are replaced by introduced annual and short-lived perennial grasses (silver grass, annual ryegrass, bromes, barley grass) in the south, and by native grazing-tolerant perennials such as wiregrass or redgrass, Parramatta grass and paddock lovegrass in the north.⁵³ Another consistent impact throughout the box-gum grassy woodlands is the loss of grazing-sensitive herbs such as orchids, rare daisies, lilies and twining legumes.⁵⁴

Different classes of livestock can vary in their impacts on native biodiversity in these systems. Sheep graze closer to the ground and browse more than cattle, while cattle wrap their tongues around forage plants and can pull them from the ground. Moderate sheep grazing for most or all of the year can inhibit eucalypt regeneration, unlike moderate to heavy cattle grazing.⁵⁵ Cattle damage and pollute wetlands, such as river margins and swamps, more than sheep because of

their inclination to wade into water and loiter in these areas. Grazing management is important in terms of impact on pastures. High-intensity grazing with sheep for a short duration with long rest periods in between is compatible with eucalypt regeneration because of the long periods of rest between short grazing periods when stock are concentrating on more palatable forage. Variants of high-intensity, short-duration, long-rest grazing management (e.g. planned grazing, cell grazing) may be less damaging for palatable plant species that decrease under set stocking or longer forms of rotational grazing,⁵⁶ but scientific information remains scarce.

Sown pastures tend to have less (or no) native plants compared to native grasslands, at least initially. In some parts of Australia, sown pastures do not persist if grazing is not managed carefully, reverting to volunteer annual or perennial pastures with varying numbers of grazing-tolerant native species. Naturalised pastures on the Northern Tablelands of NSW are some of the best pastures for fine wool production, with a balance of sown yearlong green pasture grasses and annual clovers, and volunteer summer-active native grasses.



Cattle have a greater impact on wetland systems than sheep because they wade into the water, damaging wetland vegetation and impacting on water quality.



Livestock grazing of perennial grassland on the Darling River floodplain has changed it to an ephemeral herbland.

Sown pastures in New Zealand, which occupy some 40% of the land area, are rarely invaded by native grassland species because they were previously forested, but if farm inputs are low (fertiliser, grazing pressure), they often start to revert back to native forest as species such as bracken fern and various shrubs and small trees (e.g. manuka and kanuka) invade. One native species that does do well in New Zealand sown pastures is the grass grub beetle. Prior to human settlement this was a species of native grasslands, but the larvae have become a serious pest feeding on the roots of pasture grasses.

Pastures of all kinds, including native grasslands, tend to contain fewer species of vertebrate animal than structurally more complex habitats such as shrubland, woodland or forest. However, grass and shrub-dominated pastures integrated with tree lines, shelterbelts, windbreaks and woodlots for shelter and livestock shade are more structurally complex, and contain a larger number and diversity of animals than just grass and shrub-dominated ecosystems.⁵⁷

Cropping systems

Traditional forms of cropping, both irrigated and dryland, involve the removal of all vegetation, the use of fertilisers and other soil amendments to boost crop yield, and the active suppression of other plants to minimise competition and contamination. Crops treated

with repeated insecticide applications are likely to be largely devoid of any aboveground native animals unless the target pests have developed resistance. To avoid this, there is increasing interest in the use of perimeter habitats, inter-cropping, and refuge and trap crops for natural pest control in Australia, New Zealand and elsewhere.⁵⁸ Crops, particularly irrigated fields, managed with minimal use of insecticides typically have a diverse arthropod community, including many native species of pest and predator, as well as resident bird species such as golden-headed cisticolas (old-world warbler) in Australian cotton crops, quail in cereal crops, and snakes, frogs and rodents. Like pastures, crops surrounded by windbreaks or integrated with tree and shrub lines for shelter or green manure are likely to yield a more diverse and abundant native fauna than just the crop alone, owing to the structural complexity of the trees and shrubs, the increased protection and an increased range of foraging opportunities and food sources for fauna. In Queensland cane-growing districts, replacement of the weedy verges alongside sugarcane crops by trees and tall dense native vegetation reduces the rank grass habitat for two native rats and provides habitat for predatory owls, reducing rat numbers and the damage caused to sugarcane by 80–100%.⁵⁹

Over the past 15 years, Australian farmers have experimented with various forms of cropping



Sown pastures of exotic grasses and clovers are the mainstay of New Zealand agriculture.



Former sown pasture that has reverted to a naturalised pasture of cocksfoot, redgrass and Parramatta grass on the Northern Tablelands of NSW.



Conventional dryland cropping involves replacing all aboveground vegetation with the crop, in this case wheat.

polyculture. Pasture cropping involves the sowing of a crop into a dormant or suppressed native pasture, such as sowing oats in autumn into a summer-active pasture using a tined seeding implement.⁶⁰ 'No-kill' cropping involves using a disced seeding implement to cut a slot through a dormant pasture into which the seed is drilled, minimising damage to the pasture.⁶¹ Pasture and no-kill cropping rely on the fact that winter crops can use stored soil moisture when summer-active native pastures are dormant, making more efficient use of land and autumn–winter rainfall with little or no damage to the pasture. An additional advantage is that livestock can return to the paddock as soon as the crop is harvested to graze the stubble and renascent pasture in the late spring, rather than having to resow the pasture or wait for a volunteer pasture to develop. Where the pasture contains a native component (e.g. a redgrass pasture), native plant diversity is superior to the alternative of having to spray out or plough up the pasture prior to sowing the crop.

Irrigated cropping and pastures may provide additional opportunities for native biodiversity over and above those associated with dryland farming and pastures. Irrigation water storages and tailwater dams associated with closed (bunded) irrigation systems in inland eastern Australia provide artificial wetland habitats for aquatic plants, invertebrates, and vertebrates such as waterfowl and fish.⁶² Irrigation storages can be engineered to provide a variety of aquatic wildlife habitats. Similar detention ponds and artificial wetlands



A no-kill crop of oats that yielded 1.6 tonnes/ha in a redgrass pasture paddock. (Photo courtesy of Bruce Maynard)

for filtering the runoff from cane fields provide habitat for native plants and animals in coastal Queensland.⁶³ In the Riverina in southern Australia, when irrigation water is available for rice production, the inundated fields and water distribution canals provide habitat for the nationally vulnerable southern bell frog.⁶⁴ Flood-irrigated pasture in New Zealand attracts a wide variety of waders and wetland birds during summer irrigation, including plovers, dotterels, terns, pied stilt, the endangered black stilt, and oystercatchers, as do water storage dams. In landscapes that have experienced significant wetland loss, these new wetland habitats go some way to retaining aquatic wildlife in a region.



Waders such as oystercatchers take advantage of novel feeding opportunities in flood-irrigated pasture in the Mackenzie Basin.

Horticultural systems

Horticulture and vegetable growing is a mixed bag in terms of native biodiversity. Herbaceous crops such as strawberries and vegetables provide little structural complexity for fauna as opposed to orchards of trees and shrubs. Particularly in herbaceous crops, production intensity is high and competing plants such as weeds and grasses in inter-rows are not tolerated, resulting in a monoculture of low structural diversity and little opportunity for fauna. Intensive horticulture is often characterised by high pesticide use to control arthropod pests, fungal pathogens and weeds. Vertebrate pests (e.g. fruit-eating birds and fruit bats) are often killed, excluded or scared off. Intensive herbaceous horticulture involving the heavy use of pesticides is unlikely to provide opportunities for aboveground biodiversity. On the other hand, herbaceous horticultural systems that include emergent shrub and tree rows for shelter, or shrub, vine and tree-based horticulture (e.g. vineyards, and fruit and nut orchards) are likely to provide a wider range of opportunities for fauna. This is due to the combination of shrubs or trees and the strips of herbaceous plants between the rows, where inter-row

plants are tolerated. The cover and composition of the herbaceous strips in vineyards and tree orchards can be important in terms of natural pest control. Irrigated citrus orchards in the Riverland with dense inter-row strips of diverse perennial grasses and herbs provide habitat for the natural predators of Kelly's citrus thrips. By contrast, orchards with inter-rows managed as bare ground, annual weeds or monocultures of lucerne or oats provide little refuge, requiring greater use of chemical sprays for thrips control.⁶⁵

Organic or low-pesticide production systems (such as Pacific Coast EcoBananas in north Queensland and Zespri organic green kiwifruit in New Zealand) are likely to present more opportunities for native flora or fauna than comparable conventional farming systems. A meta-analysis by Janne Bengtsson and colleagues⁶⁶ of 66 publications published up to November 2002 showed that organic farming usually increases species richness, having on average 30% more species than conventional farming systems. The authors concluded that more species of birds, insects and plants are generally found in organic than conventional farming systems, an effect most apparent at the plot scale but also evident at the



A macadamia orchard with Caribbean pine windbreaks and grassy inter-rows in north Queensland is habitat for a range of rainforest bird species.

whole-farm scale. On average, organisms were 50% more abundant in organic farming systems, particularly birds, predatory insects, soil organisms and plants at the plot and field scale. However, non-predatory insects and pests were not more abundant on organic farms. More recent studies have also shown higher levels of native biodiversity on organic compared with conventional farms.⁶⁷ However, this relationship does not hold for all groups⁶⁸ and, indeed, Bengtsson *et al.* found that 16% of studies in their meta-analysis showed a negative effect of organic farming on species richness. They concluded that the positive effects of organic farming on biodiversity are most likely in intensively managed agricultural landscapes. In districts with a variety of land uses in which agricultural fields are only one of many habitats present and biodiversity is high due to the diversity of habitats, organic farming offers less biodiversity benefits.

Farm forestry systems

Farm forestry can take one of two forms, and both are important for native biodiversity. Native forest management on farms involves the silvicultural management of naturally occurring stands of trees or shrubs to produce a range of forest products (sawn timber, fuelwood, fence posts, flowers or foliage, etc.). If the area of native forest, woodland or scrubland is managed in a manner that mimics natural regeneration processes, and disturbances associated with farming activities are excluded, the conservation values of the area can rival protected areas of comparable size. Native farm forests can provide habitat for the full complement of naturally occurring plants, animals, fungi and microbes, including threatened species, especially when invasive pest control is undertaken as part of management. Regrowth native forest of spotted gum, regenerated from failed dairy pasture in the 1930s and managed for timber production for the past 30 years, has conservation values rivalling adjacent never-cleared forest. The regrowth forest provides habitat for a range of threatened species including slaty red gum, yellow-bellied glider, brush-tailed phascogale and masked owl. Native forest managed for timber production can complement the conservation value of national parks because the fine-scale disturbances associated with tree removal, silvicultural practices and, in Australia, burning for tree regeneration, provide habitat patches



Natural pest control in organic and conventional farming systems is a commercially important ecosystem service. Here, a spined predatory shield bug is attacking a bollworm larva in wheat. (Photo: Lewis Wilson, CSIRO)

important for specific plants and animals, including nationally threatened species such as Hastings River mouse and Dorrigo daisy.⁶⁹

The second type of farm forestry involves the integration of planted tree and shrub crops in various configurations, on traditional farming or grazing properties. The trees and shrubs can occur in single or multiple straight or curved lines, blocks of varying size and shape, in monocultures or mixed plantings, around the perimeter, in the middle or throughout a paddock, as scattered individuals, and in association with herbaceous crops and pastures or in paddocks dedicated entirely to the woody crop. There are no limits to the diversity of farm forestry options possible, in terms of layout, structure, composition or companion plants and farming systems. Farm foresters are more likely to plant a diversity of tree species compared to commercial foresters who have traditionally focused on radiata pine in Australia and New Zealand. With carbon sequestration becoming a potential additional income source for farmers, or at least a means to offset carbon emissions from the farm, forestry is likely to become increasingly important on Australian and New Zealand farms.

Planted farm forestry has a significant positive impact on native biodiversity, especially fauna, because of the structural and compositional diversity it adds to traditional farming systems. Increases in bird and arthropod diversity in New Zealand, and bird, microbat, arboreal mammal, reptile and arthropod diversity in Australia have been reported in association with planted farm forestry in comparison to open pasture and crops. Plantings of native trees and shrubs provide opportunities for a wider range of native fauna than plantings of introduced species, but even pine plantations are not the ecological deserts they are often assumed to be.⁷⁰

Less attention has been paid to the native plant consequences of farm forestry and tree plantings on farms. This is probably because the outcomes for native plants are less spectacular than for fauna (native species plantings excepted). The prior history of cropping, sown pasture and fertiliser use, and commercial stocking rates, coupled with the soil disturbance and use of herbicides and fertilisers to establish trees on farms, means that the understorey plants that volunteer beneath planted trees and shrubs tend to be species favoured by soil disturbance and nutrient enrichment. Although some native species

may find these conditions favourable (e.g. weeping rice-grass in south-eastern Australia), they are unlikely to be decreaser plants of high conservation value. However, New Zealand pine plantations provide good habitat for a number of native orchids including declining species.⁷¹ More often, tree lines and woodlots fill up with introduced perennial grasses (fescue, cocksfoot, phalaris, ryegrass, paspalum) and forbs (especially weedy species), and can harbour significant populations of woody weeds (e.g. gorse and European broom).

Low versus high-input farming systems

An important conclusion from our survey of farming systems is the distinction between the effects of low and high-input systems for native biodiversity. Rangelands epitomise low-input grazing systems, while pasture cropping and no-kill cropping is as low-input as one is likely to find in farming. Native forest management is another low-input example. To the extent that low-input systems make use of or coexist with the pre-existing vegetation, rather than replace it, and the productive aspects of low-input agriculture such as conservative grazing or direct-drill cropping do little damage to



Forest woodlots are an increasingly common component of many farms in Australia and New Zealand.



Understorey of common native small tree and fern species in a New Zealand radiata pine plantation.

existing vegetation, low-input systems are highly compatible with the maintenance of native biodiversity. Conservative grazing and repeated cropping may change grassland composition over time. Notwithstanding this, low-input systems are compatible with a significant amount of native biodiversity.

By contrast, high-input systems generally involve the complete removal of pre-existing vegetation and the maintenance of the purity of the sown plant sward with few weeds and volunteer plants to minimise competition with the crop or pasture and to maintain high product quality. High-input systems also involve frequent soil disturbance and trafficking to prepare the seedbed, eliminate weeds, sow the crop or pasture, add fertiliser and other soil amendments and for harvest. Irrigation is often a feature of high-input systems, enhancing the growth of the sown crops and pastures and increasing the need for pest suppression using insecticides, fungicides and herbicides. The need for repeated replacement and suppression of non-crop and non-pasture vegetation in high-input systems, the frequent use of pesticides and the addition of water, fertilisers and soil ameliorants, all have negative consequences for most elements of the native



Low-input arid rangeland grazed by sheep on north-eastern Eyre Peninsula.

biodiversity that may linger, attempt to colonise or live adjacent to high-input fields. Exceptions have already been noted above in terms of low-pesticide or organic production systems. The Australian cotton industry has markedly reduced the use of insecticides and residual herbicides in the past 15 years, with the advent of genetically modified cottons, with positive impacts for native biodiversity. These examples are the exception, however, and high-input farming systems generally have significantly less native biodiversity associated with them than low-input systems.⁷²

Farming systems through time

It is important to remember that the nature of farming has changed greatly over time, especially in terms of extent, type and intensity. These changes have had both positive and negative impacts on native biodiversity. Biodiversity is dependent on the range of habitat opportunities available in an area, and the presence of species that are able to make use of the opportunities. Fire-stick farming as practised by Aboriginal people in central Australian deserts provides numerous opportunities for desert plants and animals to colonise recently burnt patches, the fauna and flora of the patches gradually changing as the vegetation matures and changes to long-unburnt communities. The plants and animals of central Australia have had perhaps 45 000 years to adapt to human burning and a lot longer to adapt to wildfire, and so the habitat opportunities created by patch burning are exploited by an enterprising biota. In contrast, Western

agriculture has in the space of little more than 200 years imposed novel disturbance regimes on agricultural landscapes in Australia and New Zealand, based on vegetation clearance, soil disturbance, tillage, fertiliser, soil and water amendments, pesticides and introduced plants and animals. Some native plants and animals, by chance, have prospered from farming. However, most have been eliminated because commercial production goals and land- and water-use practices for food and fibre production are incompatible with their persistence.

A key feature of Western agriculture in New Zealand and Australia has been the steady increase in extent and intensification of farming over time,⁷³ with often negative consequences for native biodiversity. As technology has developed, and the size, power, efficacy, precision and sophistication of farm machinery have increased, the ability of farmers to microregulate their land and water management has improved. Field sizes have increased, and new land and soil types formerly beyond the capacity of farm machinery have been brought into production. Up until the 1970s, cropping on the slopes and plains in north-western NSW was confined to the lighter red soils. With the advent of larger, more powerful farm machinery, the floodplain alluvial clays were brought into production. The plains grasslands that were formerly dedicated to grazing are now the focus of most of the cropping while some of the less fertile, erosion-prone red soils have been retired from cropping and returned to pasture. Cropping of the clay floodplains has progressed so quickly that native



High-input pasture dominated by exotic grass and legume species with few native species present.



Over-sown pastures dominated by ryegrass, cocksfoot, fescue and clover and maintained by regular fertiliser application are the mainstay of New Zealand agriculture and have replaced the previous native forest.



Sowing the heavy clay soils of the alluvial plains of north-west New South Wales. (Photo: Leah MacKinnon)

grasslands on alluvial plains in north-west NSW are now listed as endangered and critically endangered under state and federal legislation, respectively.

In New Zealand, the recent introduction of higher-capacity and more efficient irrigation technology associated with water extraction and distribution systems and travelling irrigators, has fostered the expansion of irrigated agriculture (especially cropping and dairy farming) into dryland areas where these types of agriculture were previously either unsuited or unreliable. As a result, remnant native biodiversity in these areas has come under increasing pressure. For example, the largest known population of the nationally endangered Canterbury mudfish was threatened by a proposal for a 1300-ha water-storage lake to supply a new irrigation scheme. Other remnant populations are being lost as irrigation systems are installed and remnant wetlands drained.⁷⁴

The increasing intensification of farming has been, in part, a response to the cost-price squeeze faced by farmers over the past 60 years. Since 1966, the Australian broadacre farming and dairy industries have suffered a 30% increase in real costs, a slight reduction in real income, and a resultant 80% reduction in real profit.⁷⁵ In New Zealand, the removal of farm subsidies in 1984 exposed the farming sector to international prices for inputs and outputs, including government services⁷⁶ and forced farmers to rethink the way they managed their land. Common farmer responses to deteriorating terms of trade and the removal of subsidies have been

to increase farm and field size to capture economies of scale, increasing the uniformity of farming landscapes, and to increase the intensity of land and water use in the drive for improved production efficiencies. Both trends are generally negative for native biodiversity. In the case of irrigated agriculture, while on-farm storage and tailwater dams in inland eastern Australia have increased greatly the area of artificial wetland available for aquatic plants and animals, this has come at the expense of the river systems and natural wetlands in the Murray–Darling Basin from whence the water has been drawn. Similar patterns are starting to emerge on New Zealand's Canterbury Plains, where water flows in the natural river systems have been steadily declining as the



Modern irrigation technology has revolutionised farming across some of the driest areas of New Zealand such as the Canterbury Plains.

area of irrigated land has increased. The contraction in area and drying out of some of the iconic wetlands in inland eastern Australia, such as the Macquarie Marshes and the Gwydir wetlands, have been a heavy price to pay for river regulation and irrigated agriculture on the driest inhabited continent.⁷⁷

There are some examples of the reverse trend of decreasing land-use intensity and abandonment of farmland in New Zealand and Australia. With the withdrawal of agricultural subsidies in New Zealand, much marginal land requiring substantial fertiliser and seed inputs to maintain productivity has been abandoned and allowed to revert to shrubland and forest. Native biodiversity is a beneficiary of these central government policy changes. In Australia, a similar withdrawal of the superphosphate bounty in 1973 saw a subsequent decline in fertiliser use, with a probable increase in naturalised and volunteer pastures dominated by native grasses in northern NSW.

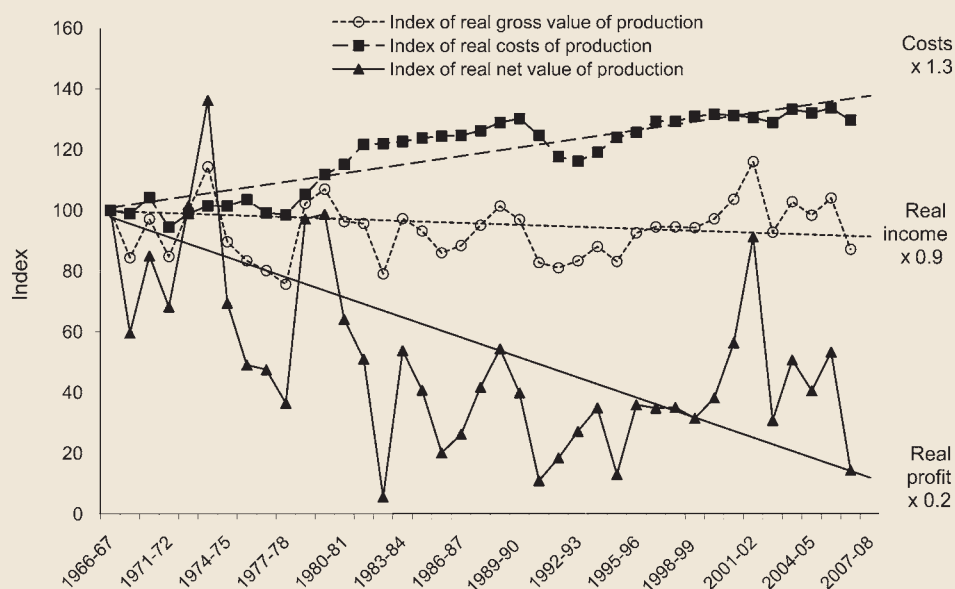
Conclusions

The pre-history of agricultural plants and animals introduced into Australian and New Zealand from the northern hemisphere and the disturbance regimes associated with European-style agriculture largely account for the responses of native biodiversity to food and fibre production. Where land- and water-use intensity and modification of the natural landscape is

low, or farming systems rely on complex vegetation structure, or agricultural management mimics pre-existing disturbance regimes, native biodiversity has generally fared well. In districts characterised by intensive land and water use, major habitat simplification such as herbaceous monocultures or sown pastures of exotic grasses and legumes, heavy applications of pesticides and novel, frequent and intensive disturbance of soils and vegetation, the resultant biodiversity is very different to the native state.



Marginal Hawke's Bay farmland reverting to kanuka shrubland after fertiliser applications ceased with the removal of subsidies.



Trends in real costs, income and profit in the Australian broadacre farming and dairy industries since 1966. (Redrawn from Gardiner and Reid)⁷⁸

4

IMPLICATIONS OF FRAGMENTATION FOR NATIVE BIODIVERSITY

Both the type of farming system and the history of agricultural development interact with the pre-settlement environment to determine the composition and structure of native biodiversity in modern agricultural landscapes. The outcomes for native biodiversity are diverse, both within and between regions and among farming systems. Differences in the nature of the pre-settlement vegetation, in the timing and extent of original and subsequent clearance, and in the development of agriculture over the last 200 years all contribute to the differences in outcomes. It is therefore difficult to generalise about biodiversity in farmland, other than to say that multiple management approaches are required to ensure that all native biodiversity persists in agricultural districts. A single generic approach to managing biodiversity will most certainly fail. We address the diversity of management approaches that are available later in this book. In this chapter, we summarise some of the ecological implications of agricultural development for native biodiversity, focusing on the effects of habitat fragmentation on remnant biodiversity, while in the following chapter we consider the native biodiversity that resides in the matrix.

Types of fragmentation

The most obvious consequence of agricultural development is the loss of native habitat and the way the remnant biodiversity is arranged spatially in the post-settlement farmscape. The process of breaking up the original habitat, whether it is grassland, woodland or forest, is referred to as ‘fragmentation’, and results in remnants of the original habitat embedded in a matrix dominated by agriculturally useful plants (usually pasture or crops). However, the process of fragmentation

is not simple, and the resultant spatial arrangement of the remnant biodiversity can vary considerably within and between regions. Landscape ecologists recognise three key elements in fragmented landscapes: remnants, corridors linking the remnants, and the matrix within which they are embedded. Both the spatial arrangement of these elements and their composition strongly influence the fate of remnant native biodiversity.⁷⁹

While simple binary landscapes with remnants and matrix can be found in intensively farmed areas, for example the wheatbelt of Western Australia or the dairy farming landscapes of New Zealand’s Waikato region, in many areas the distinction between matrix and remnant is not clear-cut. This is because remnant native biodiversity can occur as scattered individual plants through fields, as small patches in field corners, along streams or fence lines, and as extensive remnants, all with different levels of modification. The matrix might comprise predominantly native grasses and forbs although the native woody vegetation has been removed, as is the case with grasslands derived from woodlands and now used for grazing in eastern Australia. Alternatively, it might comprise exotic pasture with scattered remnant forest trees and patches of regenerating native and exotic shrubland, as is the case over much of the higher rainfall hill country of New Zealand. The term ‘variegated’ has been used to describe these landscapes.⁸⁰ In essence, fragmentation comprises three key components: the amount of original habitat (e.g. forest, woodland or grassland) remaining (e.g. 50%, 20%, 5%), how this habitat is distributed across the landscape (fewer larger patches or many smaller patches, including their size, shape and connectivity), and the degree to which remnant patches have been modified (e.g. native–exotic



A fragmented landscape with exotic pasture replacing native forest, Westland.

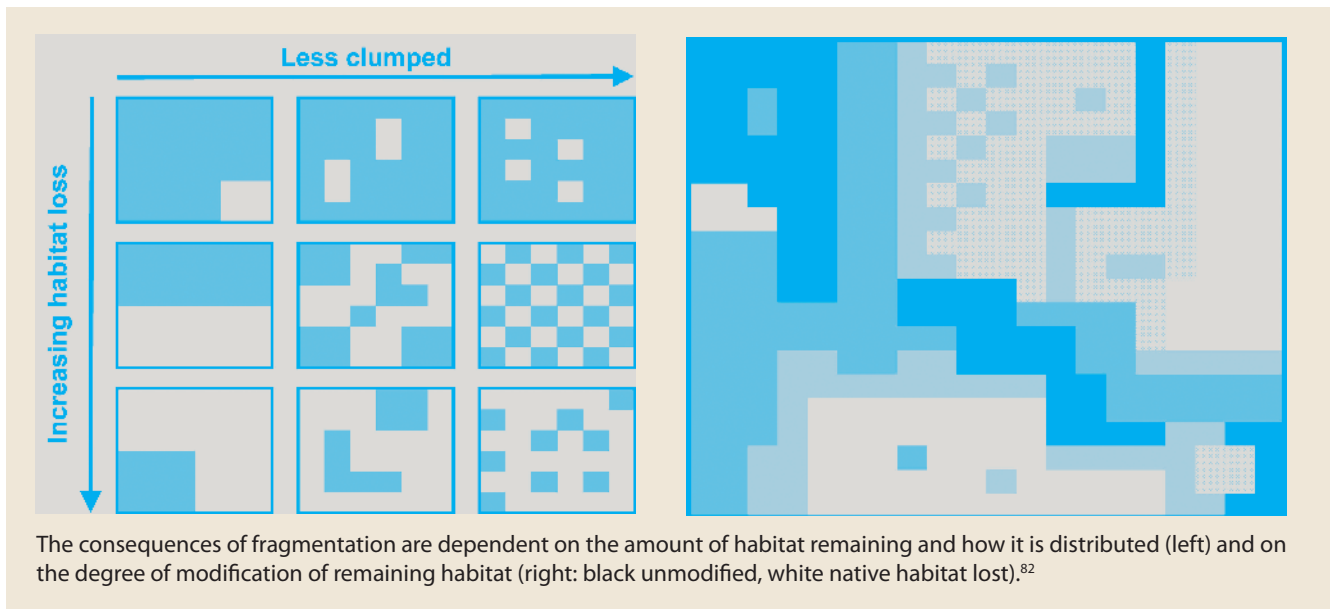


A variegated landscape of riparian frontage, crops, sown and native pastures, wooded grazing lands and forested hills on the North West Slopes of NSW.

mix, 90:10, 50:50, 20:80).⁸¹ The interaction between these three components of fragmented landscapes creates a diverse array of habitats that native species can utilise. While it is difficult to explain all the effects of fragmentation, given the diversity of ecosystems, species and biological responses, it is possible to identify the major ways in which fragmentation affects native biodiversity.

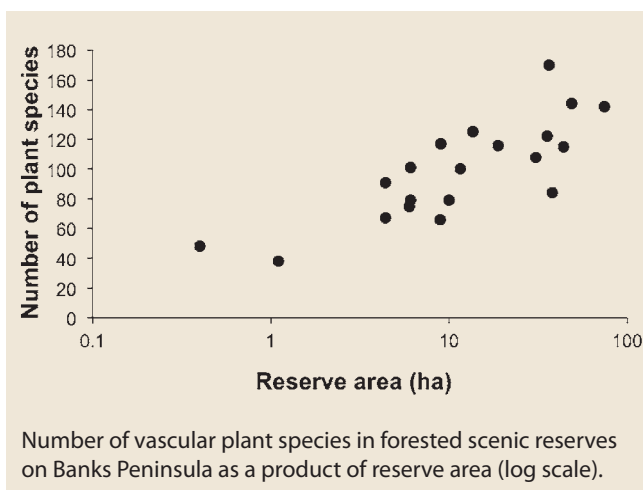
Effects of fragmentation

Fragmentation exerts an ongoing effect on remnant biota in several ways. The small areas of habitat remaining and the isolation of remnants from similar habitat are important effects. The imposition of patchiness on populations of species that were formerly continuously distributed across the landscape may be exacerbated by the effects of edges or through alterations to disturbance regimes. Finally, the effects of fragmentation may only become evident with the passage of time. Many of these effects are themselves interrelated and collectively shape much of the native biodiversity that persists in agricultural landscapes and the outcomes that can be achieved for native plants and animals with management.



Area effects

Innumerable studies have shown that there is a direct relationship between the number of species present and the area of a remnant: larger remnants tend to have more species than smaller remnants.⁸³ This is partly due to the fact that small remnants and the organisms that live in them are more vulnerable to a range of factors than large remnants and their constituent species. The few individuals of a species that remain in small remnants are more vulnerable to natural perturbations (e.g. drought, increased mortality or reduced recruitment), the influences of human activities or predation, the genetic consequences of small population size (e.g. inbreeding depression), and to chance fluctuations in population processes (e.g. a failure of individuals to mate). Species responses to area are of course not as simple as the



species–area relationship implies, with the species persisting in small remnants not being a random sample of the full suite of pre-fragmentation species. Smaller generalist species often persist in small remnants, even highly degraded ones, while closely related, larger or more specialised species are only able to persist in the largest, least modified remnants. Furthermore, the shape of the relationship between species number and area is non-linear, with the rate of decline in species number increasing with decreasing remnant area.⁸⁴

Isolation effects

Isolation is important because the chances of a species re-establishing after local extinction are lower than might have been the case before habitat loss. This occurs because the matrix between remnants is usually different to the habitat that occurred between even patchy populations of native species prior to fragmentation. This matrix imposes dispersal barriers for many species, especially those that have a strong requirement for woodland or forest interior conditions. However, as discussed earlier, most fragmented landscapes are not so black and white, with different mixtures of native and exotic species forming a variegated matrix that can provide a range of opportunities for native biodiversity to persist in or disperse through. However, the matrix also presents many challenges for native biodiversity due to ongoing agricultural practices and the presence of exotic plant and animal species. The matrix is not



Corridors of native forest following terrace edges and streams within a Westland farmscape.



Scattered trees in open agricultural landscapes in northern NSW provide stepping stones for some species.

uniform, with considerable variation sometimes within a field or farm, and certainly between different agricultural regions. The matrix in a New Zealand irrigated dairy farm harbours few native species, although waterfowl, native and exotic, may utilise the irrigated pastures. In contrast, the matrix in a southern Queensland pastoral property is usually dominated by native perennial grasses and offers considerable habitat for a range of native plants and animals.

Corridors can form key dispersal routes for mobile native species, and are important stepping stones and seed sources for the dispersal of sedentary organisms like plants, thus reducing the effect of isolation.⁸⁵ Corridors can be continuous strips of remnant native habitat between wheat fields or along rivers and streams, or may comprise small patches of native habitat forming stepping stones between more extensive remnant areas. Even scattered trees across an otherwise cleared landscape can enhance connectivity by providing stepping stones for dispersing birds, microbats and even mammals like sugar gliders.⁸⁶ For some native biodiversity, shelterbelts of exotic

trees can also act as movement corridors. Corridors, however, also have their disadvantages.⁸⁷ For example, it has been suggested that native species within corridors are more vulnerable to predation (e.g. from species that live in the matrix), and that corridors can be conduits for predators or disease vectors that utilise corridors to move between remnants.

Patch effects

While many plant and animal species have inherently patchy distributions naturally, habitat fragmentation imposes a further level of patchiness on the landscape. For some species, the sampling effect of fragmentation means that these species are absent from remnants because they were just not there originally. Mistletoes are a good example of a group of organisms that has a naturally patchy distribution: in unmodified woodlands and forests, mistletoes tend to occur in patches separated by areas with few or no mistletoes. These natural patterns are reflected in the distribution of mistletoes in fragmented forest and woodland remnants, where absence may simply reflect the pre-fragmentation distribution rather than the effects of fragmentation itself.⁸⁸ However, fragmentation also imposes patchiness on species that were more widely distributed originally. As a result many of the species in remnants are more isolated from other individuals of the same species than would have been the case pre-clearance. In today's fragmented landscapes, this is problematic for species with poor dispersal abilities. Eastern yellow robins do not occur in remnant patches of woodland smaller than 4 ha or greater than 1500 m from other patches in variegated landscapes of the Southern Tablelands of NSW. They are therefore found in very few remnants in the region and are in danger of local extinction.

Edge effects

Edges are the zone of contact between remnants and the matrix. In forest remnants, microclimates are different close to the edge than further in, with increased solar radiation and wind speeds resulting in higher temperatures and vapour pressure deficits at the edge.⁸⁹ These changes, in turn, affect the biota and result in the loss of forest interior species that cannot tolerate the altered environment. Other environmental attributes also change across edges. For example, grazing animals



Eastern yellow robins are threatened by isolation of patches of remnant woodland in pastoral landscapes of the Southern Tablelands of NSW, due to poor dispersal ability. (Photo: Bob Shepherd)



Edges are the contact point between matrix and remnant: stringybark-gum open-forest, New England Tablelands.

penetrate into remnants from edges, transferring nutrients and weed seeds as well as compacting the soil, while the influence of agricultural management (e.g. fertiliser and pesticides) is most pronounced near the edge. However, the significance of edges for remnant

biodiversity, especially in terms of microclimatic changes, depends on the nature of the vegetation. Microclimate edge effects are most pronounced in rainforest, such as occurs over much of New Zealand and Tasmania, and in pockets along the east coast of mainland Australia. In contrast, sclerophyll forest and especially woodland communities are likely to be less affected by edges because of their open nature – they are effectively edge throughout climatically. However, other edge processes such as species invasions and nutrient transfers are less influenced by vegetation type.

Disturbance effects

Fragmentation alters the intensity, frequency and timing of disturbances, which are likely to alter the viability of remnants and the ability of many plants and animals to persist long term.⁹⁰ For example, rapid urban development around Canberra has resulted in a marked reduction in fire frequency in surrounding grassy woodlands. Frequent fire is a key part of the ecology of these woodlands, allowing a diversity of species to

coexist.⁹¹ Where disturbance regimes have been modified, changes in community composition and structure through time are expected, as species dependent on the previous disturbance regime are lost (e.g. fire-dependent herbaceous legumes in these grassy woodlands). In New Zealand, the creation of levees alongside rivers prevents flooding outside defined channels. For communities dependent on periodic inundation of the floodplain, such as kahikatea-dominated forests, the absence of this disturbance regime will result in long-term changes in forest composition and structure.⁹² Remnants may also experience new disturbances or new disturbance frequencies, for example through the invasion of a novel invertebrate or vertebrate herbivore into the remnant or through changes in the frequency of existing disturbance regimes such as windthrow.

Effect of time

The time since remnant creation is a key determinant of the species composition of remnants. When a remnant is first isolated from extensive native habitat, it is likely



This woodland at Copeton Dam, north-west NSW, has not been burnt in 90 years. It has lost plant species dependent on frequent fire, but also supports plants that are only found in long unburnt sites in this region. (Photo: Peter Croft)

to contain close to a full suite of species. However, over time, various species disappear as they are unable to cope with the new environmental conditions in the remnant or are unable to recruit enough individuals to persist. This pattern is well illustrated in Riccarton Bush (Christchurch, New Zealand), a small (6.7 ha) remnant of the original tall kahikatea conifer forest that occurred on heavier soils across the lower Canterbury Plains. Detailed floristic surveys of Riccarton Bush⁹³ show that the number of plant species has declined from 106 in 1870 to 67 today, a decline of 37%. Time lags vary between different groups of organisms. For example, plants often decline more slowly than animals for a given remnant area, as plants generally have longer life spans. Thus, plants may not actually be more persistent than animals in generational terms. The term ‘living dead’ has been used to refer to organisms that are living out their physiological life spans but are no longer reproducing, a phenomenon that is common in longer-lived plants. Examples include scattered farm trees in cropping and grazing paddocks in the Australian wheat–sheep and higher rainfall zones, and trees and shrubs palatable to rabbits and sheep in the pastoral zone. In most situations, and especially when sufficient time has elapsed, remnant biotas are depleted compared to the biota in a comparable area of non-fragmented habitat. This process of species loss in remnants is known as biotic ‘relaxation’.⁹⁴

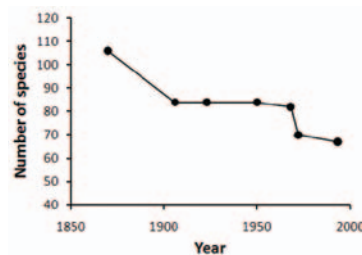
Condition of remnant habitat

Even where original habitat such as forest or woodland remains after fragmentation, human interactions with the environment, including invasive species, are likely to have had, and continue to have impacts on the suitability of that habitat for native biota. For example, selective tree removal may reduce the number of old-growth trees with cavities, which are essential for supporting many woodland birds and mammals. Leadbeater’s possum is now restricted to small pockets of old-growth mountain ash forest in the Central Highlands of Victoria because of the effects of logging and forest fire.⁹⁶ Regrowth forests also face similar challenges with regard to an absence of old-growth trees.

Invasive species exacerbate many of the effects of fragmentation. While fragmentation can make remnants more vulnerable to invasion, invasive species themselves can make remnant biotas more vulnerable



Recruitment of the slow-growing western myall in the southern Australian arid zone is suppressed by chronic rabbit and sheep grazing. The species may disappear from most of its range in the next century or two.



Decline in the number of vascular plant species through time in Riccarton Bush, Christchurch.⁹⁵



Understorey of a lowland North Island conifer–broadleaved rainforest remnant that has been heavily impacted by goats.

to the effects of fragmentation, including further invasion.⁹⁷ For example, grazed woodlands are more likely to be invaded by weed species than ungrazed woodlands. But perhaps even more significantly, the impacts of invasive predators and herbivores can be ubiquitous throughout fragmented landscapes irrespective of the scale of fragmentation. Species like foxes in Australia and stoats in New Zealand predate and have a severe impact on populations of woodland and forest animals even in the largest remnants while ungulates have a similar impact on plants in New Zealand forest remnants.

Species responses to fragmentation

Each species responds differently to fragmentation because of differences in their physiological and behavioural traits and their interactions with other organisms. Four attributes influence the response of a species to fragmentation: (1) gap-crossing ability; (2) area requirement; (3) specialised habitat requirements; and (4) edge effects.⁹⁸ These attributes are related – for example, species with specialised habitat requirements also usually have weak gap-crossing ability (i.e. their ability to cross areas different to their normal habitat,

such as farmland between forest remnants), so the effects of fragmentation can be generalised to some extent.

Generalist species capable of exploiting a wide variety of habitats and food resources (e.g. common brushtail possum in Australia or grey warbler in New Zealand) are less affected by the slight to moderate amounts of fragmentation typical of variegated landscapes than specialist species with a higher dependence on a particular habitat element or food resource (e.g. koalas in Australia or the New Zealand rifleman). This is because the proximity of remnants and the mild contrasts between matrix and fragments produce a more or less continuous usable area. Specialists requiring ‘interior’ habitat, however, may not be sustained in the same landscape, no matter how close the remnants are, and are less likely to utilise such landscapes as corridors between large areas of intact vegetation. The degree of isolation experienced by an organism subsequent to fragmentation depends on how it reacts to the scale and pattern of habitat loss, the degree of modification that has occurred, and the nature of the matrix.

Specialists also often require larger areas of habitat, have lower abilities to persist in edges, and are less likely to cross gaps or utilise corridors than generalists.



Common brushtail possums occur in a wide variety of habitats throughout Australia, including cities. (Photo: Stuart Green)



Rifleman (a New Zealand wren) is primarily a bird of native forest and mature native shrubland.

For example, malleefowl have large home ranges (up to 5 km²),⁹⁹ and are usually absent from the small remnants of mallee left in the wheat–sheep belt. Dennis Saunders¹⁰⁰ reported how malleefowl became extinct in the Kellerberrin district of south-western Australia, despite the presence of two nature reserves, 1100 and 2100 ha in area. In New Zealand's North Island, the kokako (a wattled crow) is absent from remnants under 1000 ha.¹⁰¹ In a fragmented landscape, generalists may be able to maintain a uniform distribution, while specialists assume a patchy distribution. Therefore, specialists may be particularly vulnerable to fragmentation, especially if only small remnants are left. For example, bird species on the Christchurch Port Hills, have differential survival based on their ability to forage in diverse habitats.¹⁰² The small remnants of native forest are insufficient foraging areas for many birds especially in winter, and only those species able to forage in farmland and adjacent urban areas are able to survive in substantial numbers. Birds with more restricted habitat requirements are resource-limited during winter and are either very scarce or absent.

It is possible to predict with reasonable accuracy the sorts of species that will be lost from remnants of habitat in agricultural landscapes from first principles. Among the fauna, warm-blooded animals are more prone to local extinction than cold-blooded species, because mammals and birds tend to be larger than other animals and have a higher energy requirement to sustain their larger mass and high body temperature. Thus, mammals and birds tend to have lower population densities and smaller numbers in small remnants than reptiles, frogs and invertebrates, all other things being equal. This makes them more susceptible to random fluctuations in population size and local extinction. Non-flying mammals are less mobile than birds, meaning that birds are more likely to recolonise a remnant from a source area of habitat some distance away than mammals. Birds therefore tend to persist longer than terrestrial and arboreal mammals in small remnants. However, this response is complicated by the habitat requirements of the species themselves. For example, animals that are able to utilise adjacent matrix (e.g. pasture or arable crops, termed 'generalists'), such as brushtail possums in Australia, are more likely to survive in small remnants than animals, such as



Koalas have a specialised diet of eucalypt foliage and cannot make use of crops and pastures for food, but use a wide variety of trees for resting including those in the matrix. (Photo: Karl Vernes)



A grazing-sensitive legume, native sarsaparilla or hardenbergia.

koala, that cannot make use of the matrix (termed specialists), notwithstanding differences in mobility.

Plants, on the other hand, may survive for much longer in small remnants than fragmentation-sensitive animals. Long-lived perennials like trees may survive hundreds of years, while many smaller plants have high population densities and may reproduce asexually or be capable of self-pollination, thus persisting even in small remnants. In tiny remnants of box–gum grassy woodland in south-eastern Australia (e.g. in cemeteries no greater than a hectare or two), iconic grazing-sensitive wildflowers such as native orchids, rare lilies,

daisies and legumes have been able to survive intact since the early 19th century, increasingly cut off from formerly continuous populations by clearing and grazing. Now there are little more than a handful of such sites where these species persist, but populations appear quite healthy.¹⁰³

The local extinction of one or a few key species may lead to 'higher-order effects' because some species are more important in ecosystem processes, such as pollination, dispersal, predation and decomposition, than others. Insects are a good example of a group of organisms that mediate many key ecosystem processes.¹⁰⁴ Higher-order effects of fragmentation may be less predictable than effects on individual species, because biological interactions (e.g. competition and predation) decouple the effects of physical changes on individuals through spatial or temporal lags or indirect effects. Therefore, the extent to which functioning is disrupted depends on similar factors to those influencing organisms, although higher-order effects may be counter-intuitive. For example, by decreasing the number of remnants across a landscape, inferior competitors may increase in local abundance because the frequency of patches occupied by the superior competitor decreases.



Large flowering scarlet mistletoe on a forest edge silver beech tree, Nelson.

New Zealand mistletoes illustrate how fragmentation affects individual species in complex ways according to impacts on other parts of the ecosystem. These plants are dependent on physical environmental conditions (e.g. branch growth rates, which in turn depend on light levels), the presence of appropriate host species, and seed dispersing birds for survival.¹⁰⁵ Fragmentation may benefit mistletoes by increased light levels at edges. However, habitat loss and predation have led to a decrease in the abundance of seed dispersing birds (e.g. bellbird and tui), which negatively affects mistletoe recruitment. An increase in the abundance of invasive brushtail possums as a result of better food availability in fragmented landscapes (e.g. grasses, legumes and forest-edge species) also decreases mistletoe growth and reproduction. The exact cumulative effect of these multiple relationships is poorly known, although high levels of fragmentation are probably detrimental overall to mistletoe populations.¹⁰⁶

Implications for remnant management

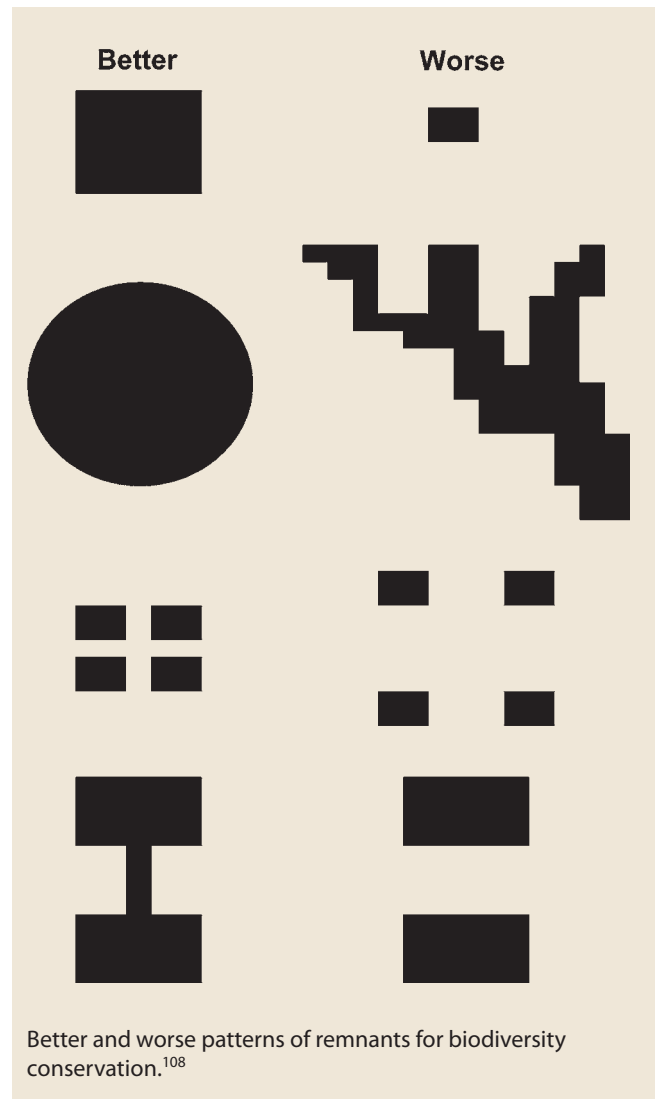
As a result of the relationship between the number of species and the area of a remnant, several geometric principles have been proposed for the biologically best arrangement of remnants.¹⁰⁷ Although these have been the subject of considerable debate in the scientific literature, they provide useful insight into the optimal arrangement of remnants in highly modified landscapes and can be an important guide for planning conservation management strategies (e.g. remnant fencing or restoration plantings). It is generally accepted that large remnants are better than small remnants because of greater habitat diversity, because they are more likely by chance to contain a greater number of species, and because they contain larger populations that are thus less vulnerable to extinction. Large remnants also are more likely to be recolonised after local extinctions because of their larger size. However, in many instances, small remnants form key components of biodiversity at the landscape scale, especially in farmscapes, because they protect particular combinations of biodiversity not present elsewhere and because they increase the total number of populations for some species. Remnants that are compact and have low perimeter-to-area ratios are better than strongly elongated remnants of the same area with high perimeter-to-area ratios. Close proximity among remnants is better



An isolated tree functions as a very small remnant, providing habitat for vagile organisms as well as valuable ecosystem services for livestock production.

than strongly isolated remnants, as there is a much greater chance of movement and dispersal of individuals between remnants. Finally, enhanced connectivity (e.g. with corridors, small remnants or even scattered trees) is generally better for biodiversity than a lack of connectivity.

In considering the spatial distribution of remnants in agricultural landscapes, it is also important to consider the disturbance regimes that occur and the potential for species in remnants to be able to respond to climate change. Larger remnants are likely to be more resilient to disturbance than small remnants (i.e. they are more likely to recover from the impact of a wind storm or fire), while small remnants are likely to be more vulnerable to disturbances originating in the matrix. In a similar manner, remnants that include greater habitat diversity are more likely to sustain species under changing climatic conditions than remnants that comprise only one habitat type. For example, detailed monitoring of the bay checkerspot butterfly near San Francisco showed that the distribution of butterflies varied depending on ambient climatic conditions, with butterflies spending more time on cooler north-facing slopes in hot, dry summers than in cooler, moister summers.^{107a} Similar topographical heterogeneity is likely to be important for



the long-term survival of many animals in Australian and New Zealand farmland.

Finally, the response of species to fragmentation depends on the spatial pattern of remnants and matrix, the composition and structure of all the different elements that make up the landscape, and the manner in which the species itself responds to these elements. The same landscape mix of matrix and remnants has very different implications for different organisms – some may find the whole landscape usable, some may use parts of it, avoiding other parts, while others will be able to use none at all and become locally extinct. The individual species responses will be dynamic through time, just as the landscape itself is, with the one caveat that the longer a species has been lost from a landscape, no matter what its configuration, the less likely it is that it will be able to re-establish.



Corridors are important linkages between vegetation remnants across agricultural landscapes, providing connectivity for tolerant wildlife.



Fragmentation patterns in Westland farmland – different species will be able to deal with this complex landscape in different ways.

Conclusions

The composition and abundance of native biodiversity dependent on remnant habitat in agricultural landscapes is a product of the fragmentation history of the area. Remnant biotas are rarely if ever static and continue to change long after the cessation of the actual fragmentation process, both because of direct fragmentation effects (e.g. the time required for remnant biotas to adjust to new conditions) and due to ongoing changes in the surrounding agricultural matrix. While the effects of fragmentation are in a sense absolute – lost habitat cannot be readily returned – conservation management can address the long-term sustainability of native biodiversity in agricultural landscapes in various ways. Strategies include manipulating the spatial pattern of remnants (e.g. through restoration plantings), through careful consideration of the way in which the matrix is managed, and through a general appreciation of the way that fragmentation has affected the remnant biota. Issues to do with the native plants and animals that reside in the matrix are considered in the next chapter.

5

NATIVE BIODIVERSITY IN THE MATRIX – THE FLIPSIDE

While agricultural development has led to a decreasing area of natural ecosystems, with an increasing proportion of these now modified, the flipside has been the increasing extent of crops, pastures, fallows, orchards, plantations, homestead gardens, artificial wetlands and wasteland dominated by agricultural and volunteer plants. These provide novel habitats for varying amounts of native biota and the exotic plants and animals that have accompanied the expansion of Western agriculture worldwide. These changes are so widespread that these new habitats form the matrix within which the remnants

of the original vegetation now occur. In Australia, the agricultural matrix comprises some 81.5 million ha (11% of the continent or 35% of the non-arid land area) while in New Zealand it accounts for as much as 13.3 million ha (50% of the total land area).¹⁰⁹ These figures are comparable to the global situation where it is estimated that 38% of the planet's land surface is now cultivated and a further 27% are dryland ecosystems grazed by domestic livestock. These figures will increase as the global population grows by a third and world food demand doubles to 2050.¹¹⁰



Fallows, crops, pastures, scattered trees, tree lines, copses, fence lines and roads characterise the agricultural matrix of the Atherton Tableland in north Queensland.

By contrast to the focus on remnants (patches) of natural ecosystems in agricultural landscapes (see Chapter 4), ecologists have been slower to focus on the matrix as a habitat for native biota, and the ecological patterns and processes of native and introduced plants and animals that live in the matrix. Yet management of the matrix is crucial to the survival of biodiversity in the remnants of the original forests, woodlands, scrublands and grasslands embedded within it,¹¹¹ as the matrix can provide both additional habitat for species living in remnants as well as influencing the quality of remnant habitat. Matrix management is also crucial to the survival of the native species that live in the farmland matrix itself, rely on it for particular resources (nesting, feeding or roosting sites), or use it for safe passage. There is evidence to suggest that some common native species in the matrix are declining,¹¹² while the importance of the matrix for remnant species will inevitably increase as the total area of land used for agricultural production increases. This chapter focuses on the patterns and processes of native biodiversity in the matrix.

Nature of the matrix

The agricultural matrix is as diverse as the nature of agriculture itself, constituting a wide range of rainfed and irrigated annual crops and pastures, perennial grass and



The agricultural matrix comprising pasture, introduced shelterbelts and plantation forest near Nelson.

herbaceous pastures, shrub and tree crops, plantations and orchards, homestead gardens, constructed water storages, and fallows and wasteland (e.g. corners, margins and headlands in planted fields). Although arid and alpine rangelands used for extensive livestock production are legitimately considered agricultural land and comprise some 60% of the area of Australia and 4% of the area of New Zealand,¹¹³ they are by definition natural or semi-natural vegetation. Such areas have undergone little deliberate vegetation modification other than by livestock grazing, the installation of water points and perhaps some over-sowing and fertiliser addition in higher rainfall districts.¹¹⁴ The remainder of this chapter focuses on the agricultural matrix (e.g. crops, pastures, orchards, plantations, farm infrastructure including farm water supplies, etc.) in the medium to high rainfall zones, and the species of plant and animal (both native and introduced) that occur in the matrix and have not been deliberately put there by the primary producer. It is less concerned about rangelands.

The animals and plants that occur in the matrix are a different assemblage to those in the pre-existing native vegetation, often markedly so. Why? The rules that govern plant and animal community assembly in farmland revolve around a few simple considerations. For plants, the presence of propagules (e.g. seeds or



Sometimes it's hard to find a native plant in the agricultural matrix: irrigated cotton. (Photo: Leticia Silberbauer)



A field of brassicas in North Canterbury, bounded by a shelterbelt of introduced trees and distant from remnant native vegetation, typifies the challenges facing native plants in the agricultural matrix.

vegetative fragments with regenerative potential), their dispersal, the microenvironment for plant establishment, and the disturbance regime are crucial. Why doesn't an early summer brassica crop in North Canterbury regenerate into the short tussock grassland that occurred there 100 years previously or the beech forest that occupied the site 650 years ago? The answer is that the seed-bank that would allow a tussock grassland or beech forest to arise in the field has long since been destroyed by countless cultivation and grazing events over the last century and repeated Maori burning prior to that. Remnants of beech forest and short tussock grassland occur some kilometres away, but the likelihood that seeds of forest or grassland species might arrive in the paddock is small. If a beech, kanaka, tussock grass or dichondra seed happened to arrive in the brassica field and managed to establish among the turnips in a soil very different to conditions encountered on the forest floor of a beech forest or in a native grassland, it would more than likely be eaten when the crop was break-fed to livestock. If it managed to survive that, it would be ploughed up with the remains of the crop to return to

ryegrass-clover pasture in the autumn. It is thus easy to see why most native plant species are no longer present in intensively managed farmland. Their seeds or vegetative propagules may occasionally disperse into a field from a remote location, but the soil, microclimate and plant competitive environment in farmland differs from a natural ecosystem and is generally unsuitable for native plant germination and establishment. On the rare occasion that such occurs, the next sheep, cow, spray, plough or vehicle tyre passing over that spot will more often than not put paid to the seedling's struggle for survival.

For animals, a somewhat different but equally deterministic set of filters influences their ability to survive in farmland. The key factors are resources, dispersal ability, other animals that influence their chances of survival (e.g. predators, competitors, mutualists) and farmland management (including hunting). If an animal is to live in the matrix it needs access to key resources: food, shelter and breeding sites. An absence of trees is for many woodland and forest birds and for almost all arboreal marsupials an absolute barrier

to their persistence in the matrix. But the situation is a little different when woodlots or shelterbelts are present, even when dominated by introduced species. For a canopy dwelling bird adapted to foraging for insects and carbohydrate from eucalypt leaves, such as the yellow-faced honeyeater, a radiata pine woodlot or shelterbelt provides no food resources. Thus, the species does not occur in pine plantings unless there are volunteer or remnant eucalypts also present.¹¹⁵ On the other hand, brown thornbills and eastern yellow robins have plenty of insect foraging habitat in the form of pine needles and branchlets for the thornbill, and low perches, bare ground, litter, coarse woody debris and scattered tussocks in the case of the perch-and-pounce robin. Most arboreal marsupials are at a double disadvantage in pine woodlots for lack of food (eucalypt, acacia and mistletoe leaves, flowers, fruits and sap) and hollows to shelter in. But as the proportion of native trees increases in the matrix, habitat quality improves for these species. New Zealand farmscapes present similar challenges for native forest birds – in these environments often the best habitats for native birds, such as the bellbird, are homestead gardens where there is a diversity of food resources.¹¹⁶

Assuming food, refuge and breeding sites are available in farmland, animals must still disperse through a heterogeneous agricultural matrix to find new mates, territories and feeding areas. Some small birds, reptiles, freshwater crustaceans and so on are physically

incapable of traversing open farmland to colonise suitable agricultural habitats in the matrix, while others are psychologically incapable of traversing large areas of open or inhospitable habitat. Forest birds such as New Zealand robins rarely traverse open farmland and are referred to as ‘obligate forest dwellers’.¹¹⁷ Young female brown treecreepers have to disperse to find new mates and territories in south-eastern Australian woodland. However, they are incapable of traversing areas of pasture and cropland greater than 2 km between patches of woodland, and are consequently declining in the wheatbelt.¹¹⁸ Assuming an animal species has the requisite abilities to disperse and navigate farmland, it must still contend with an array of other animals in the matrix, including people. Predation by introduced mustelids (mainly stoats) and rodents (mainly ship and Norway rats) is the key process threatening the survival of most vertebrates and larger invertebrates in farmland as well as native habitats in New Zealand.¹¹⁹ Most critical weight range (35–5500 g) marsupials that once occurred in the Australian wheat–sheep belt have long since become extinct. The spread of foxes through southern Australia, commencing in the latter half of the 19th century and facilitated by human persecution of dingoes and the spread of sheep and rabbits, may have been a major cause of these extinctions, along with habitat change and degradation due to overgrazing.¹²⁰ Today, reintroduction attempts are thwarted by fox predation.



Eastern yellow robins are commonly found in radiata pine plantations in south-eastern Australia. (Photo: Bob Shepherd)



A homestead garden is often rich with trees and can provide good habitat for native birds in an otherwise resource-poor farmscape, Marlborough.



The New Zealand robin is usually confined to native forest and is rarely if ever seen in open farmland, although it can occasionally be found in pine plantations in New Zealand.



Bustards are still common in sparsely populated northern Australia, where their movements are being studied using satellite trackers. (Photo: Mark Ziembicki)



Young female brown treecreepers have to disperse to find a mate, but struggle to cross open country and colonise isolated patches of woodland. They are doubly disadvantaged due to the ringbarking of mature trees early in settlement, meaning that many patches of regrowth timber lack old hollow trees for nesting. (Photo: Bob Shepherd)



Cisticolas are common and nest in transgenic cotton crops managed with a 'soft' insecticide regime in inland eastern Australia. (Photo courtesy of the Cotton Catchment Communities Cooperative Research Centre)

Humans are the final filter that animals must pass if they want to live in farmland. Iconic species such as bustards once occurred throughout natural grasslands in southern Australia, but people's penchant for eating them means that they cannot survive today's hunting pressure in settled districts.¹²¹ Farmland management can also disrupt animal populations. Prior to the introduction of transgenic cotton modified by the insertion of *Bacillus thuringiensis* genes to shield the

crop from bollworm (*Helicoverpa*) attack, cotton crops in inland eastern Australia were subject to frequent broad-spectrum insecticide applications, with up to 20 sprays in heavy pest-pressure summers. Cotton fields and surrounding areas effectively lost their invertebrate fauna, with impacts up the food chain. Invertebrates and small passerines (cisticolas and fairy-wrens) are now common in genetically modified cotton (Bollgard™) crops in summers with low pest pressure.

Effects of the matrix

As a habitat for non-crop and livestock plants and animals, the matrix varies tremendously in terms of:

- physical structure, for instance the growth forms of the dominant agricultural plants present (e.g. no plants in a fallow, or perhaps grasses, herbs, shrubs or trees as crops or forages)
- physical arrangement of the dominant agricultural plants (crop monocultures, pastures comprising intimate mixes of several forage species, zoned plantings such as engineered woodlands and alleys of herbaceous crops and pastures between rows of shrubs or trees, etc.)
- density of scattered habitat features across management units (scattered paddock trees, farm dams, etc.)
- composition in terms of the biogeographic origins of the dominant agricultural plants (local or country endemic, introduced from overseas)
- life cycle of the dominant agricultural plants (annual vs perennial)
- source of water for primary production (rainfed vs irrigated)



Dryland annual crops are monocultures in conventional Western agriculture.

- type of management (mechanical, chemical and biological) and the management regime in terms of intensity (e.g. ploughing vs direct drill vs no-till, or light vs intense grazing) and duration (e.g. continuous or year-round grazing vs pulse grazing of 1–2 days followed by 3–6 months rest).

Examples of farm enterprises that vary in critical agricultural habitat variables are provided in the table opposite.

All of these factors operating at the paddock scale influence the numbers and types of plants and animals that colonise, survive or forage in the agricultural matrix, the frequency with which volunteer plants and animals are disturbed, forced to flee or made extinct by human disturbance, and the growth and reproductive rates of the individuals and populations concerned. Perchance, stubble quail and little button-quail, take advantage of cereal growing in the southern Australian wheatbelt. They move into the crops in winter once the plants provide sufficient cover, breeding in the maturing crops in spring and early summer and feeding on grain, weed seeds and arthropods in the crop prior to harvest and the untimely disruption to nesting and fledging young caused by harvest or hay making.¹²² Brown songlarks and Australasian pipits also inhabit



Radiata pine and eucalypt agroforests with a perennial sown pasture understorey are structurally more complex and temporally more stable than annual crops.

Paddock-scale factors determining the biodiversity of native and introduced plants and animals in the agricultural matrix in Australian and New Zealand farmland.

Biodiversity element	Habitat variable	Level	Enterprise or example
Structure	Growth form of dominant agricultural plants	None	Fallow
		Grass	Grass pasture, cereal crop
		Forb	Canola or brassica crop
		Shrub	Tea tree plantation, old man saltbush forage planting, orchard
		Tree	Radiata pine woodlot, orchard
	Spatial arrangement of dominant agricultural plants	Monoculture	Cotton crop, ryegrass sward
		Mix	Multi-species (e.g. fescue, ryegrass and clover) pasture
		Zoned	Tagasaste–pasture alley farming, engineered woodland (tree rows and pasture alleys), orchard
	Presence of isolated keystone habitat elements	Type	Rock outcrop in a pasture, isolated paddock trees, wetland
Composition	Biogeographic origin of dominant agricultural plants	Local native	Tea tree plantation
		Non-local native	Macadamia plantation
		Introduced	Wheat crop, ryegrass, clover
	Life cycle of dominant agricultural plants	Annual	Barley crop
		Perennial	Apple orchard, ryegrass–clover pasture
Function	Source of water	Rainfed	Dryland sorghum crop, sown pasture
		Irrigated	Rice crop, sown pasture
	Type of agricultural disturbance	Biological	Livestock grazing, sown plants
		Mechanical	Soil cultivation, slashing, drilling
		Chemical	Herbicides, insecticides, fungicides
		Fertiliser amendment	Manure, chemical fertilisers, green manuring
		Fire	Stubble burning
	Frequency of agricultural disturbance	Infrequent (once every 5–10 years)	Timber thinning and harvest
		Annual (once per year)	Stone-fruit harvest
		Frequent (2–5 times per year)	Cultivation or herbicide spraying for weed control, number of grazing events in planned or time-controlled grazing
		Very frequent (6–20 times per growing season)	Insecticide sprays to control bollworm and other pests in conventional irrigated cotton in a summer of high insect pressure
		Continuous	Year-round grazing ('set-stocking')
	Intensity of agricultural disturbance	Low intensity	Conservative grazing (low stock density), low-intensity spring burning of C ₄ grass-dominated pastures (for green pick), direct-drill cultivation
		High intensity	High-intensity grazing in time-controlled or planned grazing, high-intensity fire after eucalypt logging, ploughing, irrigation, fertiliser application

cereal crops in southern and eastern Australia in spring, perhaps suffering a similar fate.¹²³ Birds of prey such as black falcons and black kites often follow cereal harvesters in southern Australia to catch the array of birds, rodents, lizards and large insects forced to flee crops or injured by the machinery at harvest time.¹²⁴ Similarly, black-backed gulls follow the plough in New Zealand to prey on the invertebrates disturbed and exposed by tillage. An array of native and introduced waterbirds including variable stilts, oystercatchers, paradise shelduck, gulls and plovers take advantage of pasture irrigation on New Zealand farms, feeding in large flocks on invertebrates forced to the surface in flood-irrigated pastures. Australasian harriers have benefited from agriculture in New Zealand where they now occur widely across farmland feeding on small mammals (especially rabbits) and birds.

Plants and animals in the matrix are affected by a number of farm and district-scale factors. In particular, the heterogeneity or patchiness of the agricultural matrix influences biodiversity patterns. Some farming districts are dominated by a monoculture of only one crop such as wheat or cotton with little else in the landscape other than power lines, fences and roads. Other farming landscapes are a mixture of different

crop types (e.g. mixed cereal and oilseed crops), or combine shelterbelts (often exotic) with sown pastures, while mixed farming districts combine crops and pastures.

Diversified agricultural districts, such as the Clare district in South Australia or the Bay of Plenty in New Zealand, comprise a heterogeneous mix of crops, pastures, orchards and timber plantings, providing many different kinds of habitat. The mix and extent of matrix habitats determine the abundance and diversity of the biota that live there. In general, a region dominated by wheat crops like the wheat-growing districts of Ceduna on the west coast of South Australia or southern south-western Australia will support a small number of native species that like cereal fields (e.g. songlarks, quails and pipits), but those populations will be continuous across the landscape and common due to the abundance of habitat. In agriculturally diverse districts with a variety of agricultural enterprises, the range of native and introduced plant and animal species present will be much greater, but the population sizes of most will be low as more species try to fit into the available habitat and are constrained by inter-specific competition for resources.



Stubble quail commonly breed in spring in cereal crops in southern Australia. (Photo: Lynn Pedler)



Male (left) and female paradise shelducks are found widely across New Zealand farmland, especially where water is readily available.



Holmes Bay, Banks Peninsula – a diverse farmscape with sown pasture, horticulture, woodlots, unimproved grasslands, and native shrubland and forest remnants.



Crops provide abundant habitat for grassland species, including the Australian bustard (right). (Photo right: Rhiannon Smith)

Another spatial factor likely to be important to matrix biota in farmland is the ‘grain size’ of the heterogeneity, that is, whether the patchiness or scale of different agricultural habitats (crops, fields and farms) is finely or coarsely distributed across the farmscape. Small paddocks are likely to provide different opportunities to large paddocks. A classic demonstration of this principle is the work of Craig James, Jill Landsberg and Steve Morton¹²⁵ in the rangelands of arid southern Australia. Large industrial paddocks with one water point often exceed the walking capacity of sheep and cattle to forage away from water (5 and 10 km, respectively), meaning that the areas furthest from water are never grazed, and sustain plant and animal species intolerant of grazing. The rangeland in more finely subdivided station country is entirely within grazing distance, and therefore the native biota that survive have to be tolerant of livestock grazing, to the detriment of grazing-sensitive biota. A different example is the foraging restriction of scoliid wasps across sown pastures on the Northern Tablelands of NSW. Scoliids can only forage up to 200 m from nectar sources in native vegetation in search of pasture scarab larvae to parasitise. This means that pasture paddocks fringed with native vegetation belts need to be restricted to 400 m in size if graziers are to benefit from the natural pest control function of native wasps in grazing country afflicted by eucalypt dieback.¹²⁶

A final area-wide factor influencing biodiversity at a district scale is the temporal concordance of



Scoliid wasps are dependent on the nectar of shrubs and herbs for energy, such as this blackthorn, and don’t fly further than 200 m from food sources into pasture to parasitise scarab larvae in the soil.

management activities between one ‘patch’ (paddock or farm) and another. Area-wide grower groups in Australian irrigated cropping districts synchronise management to their advantage by applying narrow-spectrum pesticide formulations at the same time for targeted area-wide suppression of specific pests, while minimising disruption to the beneficial arthropods that provide broad pest control.¹²⁷ District-wide coordination of fox baiting in the higher rainfall sheep rangelands and wheat–sheep belt of southern and eastern Australia is based on the same principle. In New Zealand, the native bush falcon successfully nests in recently harvested

Area-wide factors determining the biodiversity of native and introduced plants and animals in the agricultural matrix.			
Biodiversity element	Habitat variable	Level	Enterprise or example
Spatial heterogeneity	Spatial heterogeneity of agricultural habitats and enterprises	Low heterogeneity	Dryland wheat
		High heterogeneity	Subtropical mixed farming with summer and winter crops, sown and native pastures and tree plantings
Grain size	Average field or paddock (management unit) area	Fine-scale variability: small paddock size	Horticulture (hops, stone fruit, kiwifruit and grapes)
		Coarse-scale variability: large paddock size	Dryland farming
Temporal concordance	Temporal concordance in disturbance regime	Low temporal concordance	Grazing events in time-controlled or planned grazing systems; district-wide variation in occurrence of fallows, stubbles and green crops
		High temporal concordance	Yearling grazing regimes; seasonal coincidence of stubbles, fallows and green crops



New Zealand falcons nest in recent clear cuts in radiata pine plantations. Forestry companies avoid working these areas during the breeding season.

compartments within extensive areas of plantation forest. In order to minimise impacts on falcon nesting, forestry operations such as site preparation are restricted during the breeding season near falcon nests.¹²⁸

Spatial patterns of native biodiversity in the matrix

Ecological theory allows us to make several general observations about the patterns of biodiversity in the agricultural matrix, although this area of study needs a lot more work.

Area effects

A universal law in ecology is that the number of species increases with the size of the area of habitat. In other words, one expects to find more species of bird or weed in a large wheat crop than a small one, all other things being equal, and more species across all the wheat fields in a region than in a single wheat crop or on just one farm. This species–area rule is driven by two factors, chance and heterogeneity.¹²⁹ First, the bigger the area, the more likely one is to encounter new species due to chance alone. Second, the bigger the area, the more likely it is to encompass subtle microenvironmental



The bigger the area the more species it contains; a very large subtropical grassland paddock is likely to have more species than a smaller paddock of the same vegetation type.

differences in habitat, meaning a greater array of different niches and opportunities for different species to occur, although in the context of the agricultural matrix this will be modified by the nature of farming activities – some farming activities such as cultivation and pesticide application over even very large paddocks may well result in surprisingly uniform conditions.

Isolation effects

Another classic relationship from island biogeography concerns the interaction between area of habitat and the effects of isolation, immigration and extinction. Simply put, a large agricultural field close to an extensive farming district should contain more matrix species than a small field remote from the farming district, because the large field is a closer, larger target for colonising species and will attract more immigrant species. Due to the area effect, it should also support more individuals of successful colonising species than the small field. Therefore, species are less likely to be lost from the large field due to random local extinctions. The isolation effect of agricultural fields is often seen in the pest control literature. Small areas of crop or plantation remote from similar areas generally suffer little pest pressure compared to large areas adjacent to or within extensive cropping or plantation districts.¹³⁰ Conversely, the plants in small isolated fields often receive better pollinator service.¹³¹ Whether these patterns are due to the difficulty of pests colonising

small areas of remote plantings or the efficacy of the natural pest control and pollination services provided by fauna in the non-agricultural habitats surrounding a small area of crop, is moot, but is usually ascribed to the latter rather than to the effect of isolation.

Connectivity

Connectivity refers to the permeability of landscapes and the aquatic environment, and the movement of resources and biota through both. At least three separate meanings of the term need to be distinguished to avoid semantic argument:¹³² (1) habitat connectivity, or the ability of an animal or plant to move through the matrix; (2) landscape connectivity, or the physical links connecting areas of farmland of the same type; and (3) ecological connectivity, or the permeability of farmscapes to ecological processes such as wind run, runoff or subsurface groundwater movement. Here we focus mainly on habitat connectivity.

The ability of native animals and plants to move across farmland and colonise suitable patches of



Despite its isolation, common mynas (inset) have colonised this small area of farmland in the middle of the 50 000-ha Macleay Wilderness and World Heritage Area although many other matrix species might not reach this site because of its isolation.



Canterbury farmscape with a mixture of elements (pastures, crops, woodlots, shelterbelts and remnants) that provides good connectivity for matrix species.

agricultural habitat limits many species from occurring more widely in farming districts, as demonstrated by on-farm plantings of local native trees and shrubs that thrive, once returned to their former environment. In many cases, the failure of native biota to be able to traverse farmland is a question of scale: the distances to be covered by a seed or an emigrating juvenile and the lack of protection from inhospitable conditions in transit are just too great for either to have much chance of arriving in a distant farmland refuge. Most plant seed and propagules only disperse a relatively short distance, despite elaborate dispersal adaptations. Similarly, although animals of open habitats are likely to attempt to move across open but unsuitable habitat, many animals of closed habitats (forests and woodlands) are unable to cross large open areas either due to psychological or physical limitations. It follows that farmland could be redesigned to include a latticework or scatter of patches of different habitats suitable for a wide range of native plants and animals at relatively fine scale.

In dieback-affected temperate pastures in south-eastern Australia, latticeworks of native tree, shrub and wildflower plantings have been suggested at 400-m intervals across farmland to provide habitat for the natural pest control agents (native scoliid and tiphiid wasps and insectivorous birds) that control the defoliating insects that are responsible for eucalypt dieback.¹³³



Latticework of native and introduced tree plantings enhancing connectivity of tree and shrub-dependent species across the matrix on the Northern Tablelands of NSW.

Edge effects

Another common biodiversity pattern is the effect of edges, where more species of plant and animal are found at or near a boundary between two distinct habitats than deep within either habitat. For instance, one might observe an increase in diversity of plants or animals at the edge between the agricultural matrix and an adjacent area of forest or woodland. Edge effects are attributable to two phenomena. Plants and animals whose habitat is squarely centred in either the agricultural matrix or adjacent native vegetation may nonetheless occasionally stray a short way into the adjacent habitat. Agricultural weed and crop plant seed may disperse a short way into adjacent woodland or forest and germinate but not persist. Similarly, willie wagtails and other flycatchers may forage along the edges of a crop or pasture, but avoid venturing too far from the shelter of trees. The second reason for an increase in species diversity at habitat boundaries concerns edge specialists, species that thrive in the intermediate ('ecotonal') environment along the boundary. Pohuehue (a native New Zealand muehlenbeckia vine) thrives at forest margins due to the high light environment. Fence lines can also represent important 'edge' habitats as they are usually not cultivated and can provide refuge for a greater range of species than occur within the main part of the paddock.



Native plants (bracken fern and cabbage tree) persisting along a fence line on the Canterbury Plains.



Some farmers manage for increased primary productivity and biodiversity by planting trees, shrubs and crops into pastures and encouraging edge effects and plant mixtures, such as this mix of summer and winter-active grasses in old man saltbush alleys.

Edge effects involving native mammals and birds have been documented repeatedly along the boundaries of native eucalypt forest and radiata pine, hoop pine and eucalypt plantations in southern and eastern Australia.¹³⁴ The highest diversity and abundance of small mammals, birds and microbats have been documented in plantations adjacent to native forest. In some cases, high native animal diversity has been associated with the greater occurrence of native understorey or remnant native trees along plantation edges than in plantation interiors. In a similar manner, native plants can occur at higher densities in agricultural fields close to remnant edges than further into the field because of the increased seed rain associated with the remnant.



Horsfield's bushlark in wheat stubble. (Photo: Lynn Pedler)

Patch effects

Different habitats provide opportunities for plants and animals requiring different resources. Crops, pastures, shrub plantings, woodlots, shrub and timber belts, farm dams, irrigation channels, bore drains and so on, all provide different resources and habitat opportunities and thus support different plants and animals. One expects to see aquatic plants and waterbirds in farm dams, for instance. It is not surprising to see ephemeral weeds of cultivation and pipits, songlarks and bushlarks in annual crops and pastures, or invasive perennial plants and birds requiring a shrub layer such as fairy-wrens in shrub plantings, such as stands of old man saltbush. Likewise, it is not unusual to encounter canopy dwelling fauna and longer lived woody plants volunteering in planted woodlots of trees (e.g. tree ferns establishing in mature pine woodlots).

As a general rule, the more similar an agricultural habitat is to a natural ecosystem, the more species of native plant and animal from the native ecosystem that are likely to occur in the farmland habitat. In New Zealand short tussock grasslands, many native species persist even when the grasslands are fertilised and over-sown with exotic grasses and legumes, with the tussocks often showing more vigour with fertiliser addition.¹³⁵ However, when they are also irrigated or cultivated, very few if any native plant species persist. In a similar fashion, unfertilised native pastures that have had the tree layer removed commonly provide habitat for as many as 84 native species on the Northern

Tablelands of NSW.¹³⁶ An additional 40 native species are found in adjacent grazed grassy woodland and open-forest, including understorey shrubs, tree seedlings and tree-commensals such as climbing saltbush. However, in cultivated paddocks that have been cropped and sown to pasture but have since reverted to native dominance, only 58 native species are found. These data also illustrate the phenomenon noted above that a mosaic of different kinds of crop, pasture, orchard and planted woodlot provides habitat for a greater diversity of matrix species than any one kind of agricultural system.

Novel agricultural habitats do not always support a reduced number of native species compared to the pre-existing native vegetation or wetland. Sometimes native species of conservation significance can be more abundant in matrix habitats than in native vegetation. Although pine and eucalypt woodlots in Australia are inhabited by a somewhat different assemblage of birds to the native forest or woodland they replaced, some native species are as abundant or are more abundant in pine and eucalypt plantings than native forest. Such birds include at risk species, such as the rufous whistler, eastern yellow robin, olive whistler, speckled warbler and white-browed woodswallow.¹³⁷

Habitat patchiness can be as fine-scaled as individual plants, with scattered large trees in otherwise inhospitable landscapes being important keystone structures for mobile vertebrates. Introduced camphor laurels are important stepping stones in dairy country for fruit

bats and fruit pigeons moving between sparse patches of subtropical rainforest and wet sclerophyll forest in northern New South Wales.¹³⁸ Isolated paddock trees in south-eastern Australia are important staging posts and refuelling stops for many birds moving through overcleared pastoral landscapes in south-eastern Australia.¹³⁹ These same trees are foci for native birds and mammals when incorporated within radiata pine and eucalypt plantations in the same region.¹⁴⁰ In New Zealand farmscapes planted trees can be important for some native bird species. For example, kereru (New Zealand pigeon) feed on willow foliage in spring and fruit trees in homestead gardens in autumn, supplementing food sources from native forest remnants.



Bassian thrushes are common in radiata pine plantations in the Mount Lofty Ranges, South Australia. (Photo: Lydia Paton)



Grazed grassy open-forest on the Northern Tablelands of NSW contains more native groundstorey species than derived native grassland or sown pastures. (Photo: Jodie Reseigh)



Kereru feeding on willow foliage in spring.



Scattered paddock trees provide important habitat connectivity for various tree-dependent birds and mammals moving through farmland.

The overwhelming role of agricultural management

The effects of the above factors on biodiversity in the matrix are strongly influenced by the nature of the matrix itself, including the manner in which it is managed. Thus fields of the same size or degree of isolation will not necessarily support the same amount or type of native biodiversity if management differs – a wheat field versus a fallow, for instance, or a set-stocked versus a planned grazed property. The overwhelming influence of management – in ecological parlance, the type, intensity and frequency of agricultural disturbances – plays a key role in modifying the spatial effects of area, isolation, edges, connectivity and patch type.

To an ecologist, a ‘disturbance’ is any unexpected abiotic or novel biotic phenomenon that disrupts an established population or community of plants or animals. Natural disturbances in most types of native vegetation (e.g. wind storms in rainforest or fire in savanna woodlands) are essential for the long-term persistence of the biodiversity of such ecosystems. The nature of anthropogenic disturbance in the matrix is, however, quite different and includes vegetation clearance, selective thinning, cultivation, sowing, slashing, pesticide application, fertilisation, irrigation, burning, grazing by ungulates, rabbits and hares, and so on. Most of these disturbances are novel with respect to the evolutionary experience of Australasian native plants and animals that are affected. Due to

differences in the functional attributes of various species of plant and animal, they do not respond uniformly to these disturbances. Species vary in their tolerance or sensitivity to a given disturbance, but tolerance of one kind of disturbance does not necessarily confer resistance to other kinds of disturbance or to the same disturbance in different seasons or at a different stage of the life cycle. Thus many broadleaved agricultural plants can withstand the passage of fire as seed in the soil seed-bank but are killed by fire when vegetative or mature. By contrast, many perennial native grasses are adapted to periodic fire and simply resprout from the base following burning. Certain kinds of tillage such as minimum till or no-till enable a pasture to persist post-cultivation,¹⁴¹ whereas conventional cultivation is designed to eliminate the herbaceous sward and conserve soil moisture or minimise competition with a newly sown crop.

In New Zealand the situation is complicated further by the fact that most pasture has been established on sites that were previously dominated by rainforest. Because of this, there are very few native species that are able to tolerate the disturbances associated with pasture management (cultivation, sowing, fertilisation, irrigation, grazing by ungulates, fire) and as a result the pasture sward is usually exclusively dominated by exotic grasses and forbs. When seed sources of forest species are present and management inputs have been reduced (e.g. reduced grazing pressure and no fertiliser addition), native woody species can establish in the grass sward and



Harvest time can be disruptive for the wildlife living in crops and pastures, NSW. (Photo courtesy of the Cotton Catchment Communities Cooperative Research Centre)

develop towards native forest. However, any resumption of farm management inputs (especially grazing or fire) will return the system to a pasture state.

Different intensities or frequencies of livestock grazing can have a dramatic impact on pasture composition and biomass. Over the past 40 years, variants of rotational grazing characterised by pulses of intense grazing followed by long periods of rest have been developed and promoted by Allan Savory, Stan Parsons and others.¹⁴² In the hands of accomplished practitioners, these forms of grazing tend to lead to high-biomass pastures dominated by palatable perennial grasses, whereas similar pastures continuously grazed for a similar number of total grazing days have lower biomass, less groundcover and litter and a greater proportion of unpalatable species.¹⁴³

In New Zealand grasslands where silver tussock dominated after Polynesian deforestation, grazing intensity can have a major influence on the persistence of native grassland species in the face of intense competition from mainly European grass species. High-intensity grazing by livestock results in the elimination of tussocks and most native plant species. On the other hand, too little or no grazing can also result in the loss of native biodiversity, as a result of competition with vigorous introduced grass species such as cocksfoot. In these systems, intermediate grazing intensities are often the best for native biodiversity, as they keep the abundance of exotic grasses in check, thus allowing native species to persist.¹⁴⁴



Young kanuka, a native seral tree species, establishing in a New Zealand exotic grassland after removal of cattle and sheep grazing.



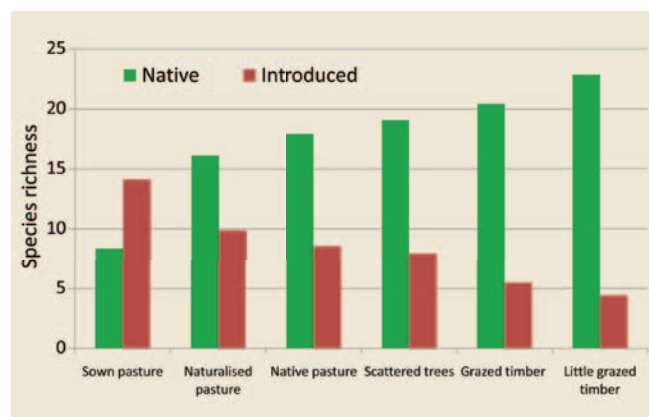
A hickory wattle establishing in a planned-grazed native pasture, subjected to high-intensity, short-duration, long-rest grazing by sheep and cattle. However, wattles never establish in comparable paddocks continuously grazed by sheep.



High-intensity, short-duration grazing by sheep in a New England grassy woodland.



Contrasting grazing regimes with different consequences for the density and vigour of silver tussock on either side of this Banks Peninsula property boundary fence line.



Average number of understorey plant species in 30-m² plots (n = 87) stratified by decreasing intensity of management inputs from sown fertilised pasture to little grazed timber on the Northern Tablelands of NSW.¹⁴⁵ Data are pooled over all major substrates (basalt, granite and metamorphosed sediment). 'Naturalised' means that the pasture was cultivated and sown to crop or pasture but has since reverted to native dominance. 'Native pasture' means a derived grassland that is dominated by native species and has never been cultivated.

A general rule concerning disturbance and its effect on transformed agricultural habitats is that the array of native species that persist in a farmscape is greater whenever: (1) the agricultural disturbance regime is more similar to the pre-existing pattern of perturbation; (2) the novel agricultural disturbance regime is less intense and frequent; and (3) the agricultural matrix is more similar to the pre-existing habitat in structure, composition and function. This is neatly shown in the gradient in native and introduced understorey plant richness in commercially grazed and ungrazed habitats on the Northern Tablelands of NSW. Ungrazed or little grazed woodland has the greatest number of native species and few introduced plants. At the other extreme, where native vegetation has been cleared and sown pastures of introduced species established, exotics outnumber native pasture species by about two to one. However, one of the challenges in managing grazing as a disturbance in the agricultural matrix in both Australia and



Damage to climbing saltbush from herbicide spray drift beneath regrowth coolibah woodland, adjacent to a dryland fallow. The sprayed saltbush shrubs are brown.

New Zealand is a lack of data on the influence of different types of grazing management and grazing animal (e.g. cattle vs sheep) on species richness, pasture composition, structure and function, or the population dynamics of individual species.

Agricultural management of farmland is also fundamentally important for its impacts on remnants (Chapter 4). The matrix and the remnants embedded within it are intimately connected – what happens in the matrix can have fundamental implications for remnants and this is nowhere more significant than in relation to matrix disturbance regimes. Grazing, fertiliser, herbicides, burning and many other types of agricultural management can and do impact on native biodiversity in remnants. Managers of native biodiversity in farmland needs to be aware of these interconnections and the profound changes they can cause.

Species response to matrix development and change

A rule of ecology is that nothing stays the same. This is likely to be as true in farmland as anywhere else, perhaps more so as the severity and frequency of agricultural disturbance regimes is greater and many of the habitats are more ephemeral (e.g. annual and short-lived perennial crops and pastures) than many natural ecosystems dominated by long-lived trees and tussock grasses. Highly disturbed ecosystems consisting of short-lived plants are more likely to exhibit reorganisation and phase change than stable ecosystems dominated by long-lived perennials, because the frequent destruction of biomass and development of gaps permits repeated opportunities to establish new biotic mixes in farmland. Thus, matrix communities are likely to be more dynamic and transitory than natural communities, at least where agricultural ecosystems are dominated by short-lived plants subject to frequent, intense disturbance.



Within a few decades of the founding of the city of Adelaide and the development of the wheatbelt in the north of South Australia, crested pigeons had colonised the newly established farmland and urban habitats from the arid zone. (Photo: Lydia Paton)

The likelihood for evolutionary change in biota that use or could potentially use farmland is high because agricultural habitats are dynamic and under-exploited due to their novelty and the lack of time for genetic adaptation of organisms and for species packing to have occurred. The continuous arrival of new crop and pasture pests and weeds in farmland is testimony to the changing distributions of existing biota and chance dispersal events, the changing genetic and adaptive profile of species to better exploit farmland habitats, and the changing nature of farming practice. The rapid evolution of genetic resistance of vertebrate and invertebrate pests, parasites and weeds to agricultural pesticides, livestock drenches and pest-specific pathogens is evidence of the volatility to expect in the composition of matrix communities and the speed with which new plants and animals are likely to invade and expand into newly created farmland niches.

As vegetation ages, many of its habitat attributes, including structural, compositional and functional features, change. As resource availability changes, so too

does the biota associated with it, as the habitat becomes less suitable for one suite of plants and animals and more suitable for another. Vegetation change can happen in as short a time frame as the 5 months that a wheat crop requires to germinate, grow, mature and senesce. Many plants (weeds) and animals (birds of cereal crops) take advantage of the changing conditions associated with a wheat crop, and live and reproduce successfully in the time between germination and harvest. Brown songlarks are spring migrants to southern Australia from central and northern Australia, arriving in the cereal growing districts of northern Victoria, southern South Australia and south-western Australia in August–September when the crops are half grown, laying eggs in October and fledging young by early November, usually before the late November–December harvest.¹⁴⁶ Brown songlarks winter in long-grass savannas in northern Australia between March and August, arriving across the Top End towards the end of the summer monsoon when the grass is actively growing and most productive. As the dry season progresses, productivity declines, prompting the

population to head south again for the summer. Thus, by coincidence, actively growing cereal fields in the southern Australian wheatbelt in August–September are sufficiently similar to savanna grasslands towards the end of the summer monsoon for songlarks to be able to exploit wheat fields and raise their young prior to harvest and subsequent grazing, burning and fallowing.

Perennial vegetation develops more slowly and the corresponding changes in associated fauna and flora are correspondingly slower. For instance, when a pine plantation is established in southern temperate Australia, about 6–8 years pass before the young trees close canopy and shade out the herbaceous understorey, forcing livestock grazing to cease for a time and reducing the value of dense unthinned stands for native herbivores such as common wombats.¹⁴⁷ A succession of understorey plants and birds is associated with aging radiata pine plantations in south-eastern Australia, native bird diversity increasing at each successive stage in stand development. Open-country birds are common in newly planted sites, with the bird community becoming more similar to that in adjacent eucalypt forest as the pines age.¹⁴⁸ Ground and understorey feeding insectivorous birds predominate in mature radiata pine, with few herbivorous species or birds that feed

in eucalypt canopies. Similar changes in understorey vegetation and invertebrate communities occur in New Zealand pine plantation as they age.¹⁴⁹ In New Zealand hill country, where the native forests were removed by Maori and Europeans, pastoralists must actively manage temperate pastures with fertiliser, seed, livestock grazing and herbicide to prevent the natural succession back to manuka and kanuka scrub, and ultimately beech and conifer forest.¹⁵⁰

Implications for matrix management as habitat for native biodiversity

The implications for matrix management as a habitat for native biodiversity are many and varied. Although the 2005 Millennium Ecosystem Assessment found that ecosystem transformation to meet human needs was the principal reason for the loss of planetary biodiversity, the extinction spasm in train will be more extreme still if the matrix itself loses capacity to support native biodiversity.¹⁵¹ Thus, a key message to farmers and agriculturalists is that the matrix matters – it is vitally important to the future of native biodiversity the world over. The way in which crops, pastures, orchards, tree plantings and farm water supplies are managed is critical to the survival of not only the common plants



Brown songlarks commonly breed in winter cereal crops during spring in southern Australia. (Photo: Lynn Pedler)



The matrix matters! Brolgas in cereal stubble in north-west NSW. (Photo courtesy of the Cotton Catchment Communities Cooperative Research Centre)

and animals of different types of farmland, but the many native species that are rare or only infrequently use farmland or are largely confined to remnant patches of native vegetation scattered through farmland.

David Lindenmayer and colleagues recently developed a checklist of issues to consider when planning the conservation of native biodiversity in heterogeneous landscapes,¹⁵² such as those that typify the agricultural matrix. We paraphrase them here:

- Manage the entire matrix for native biodiversity, not just individual bits (because it is all potentially important)
- Consider both the amount and configuration of different land cover types (habitats, fields, paddocks, blocks, etc.) in managing for native biodiversity
- Identify and prioritise disproportionately important species (e.g. rare plants or animals), processes (e.g. particularly favourable or destructive management practices) and elements (e.g. particularly important habitats) in the farmscape
- In managing aquatic and terrestrial environments on farms, think of them as interconnected and interdependent
- Make sure one's thinking and conceptual frameworks about biodiversity are appropriate to the local farm and district context and to management priorities for local native plants and animals
- Maintain the regenerative ability and resilience of farmscapes and use management to engineer new opportunities for native biodiversity
- Expect, anticipate and be ready to manage change
- Be prepared for the long haul, bearing in mind that some management activities have to be undertaken continuously given the limitations of current technology (e.g. predator control in mainland New Zealand¹⁵³ or fox control in Australian sheeplands), some actions may not have a pay-off for decades, and that some mistakes could take decades to undo and are therefore best avoided



The native component of the novel assemblages of plants and animals found in farmland has significant value for biodiversity conservation.



Fencing off this on-farm storage has created a source of clean drinking water for livestock, wildlife habitat and a recreation asset.

- Approach management as an experiment to learn from: Did it work? Can it be done better next time?
- A range of management approaches for native biodiversity conservation may be necessary in farmland, both single-species and ecosystem-wide approaches, targeting the highest priorities
- Consider managing at multiple scales, for instance at the scale of the:
 - o homestead garden (get rid of the cat)
 - o farm dam (exclude livestock from half of it and allow reeds and rushes to grow)
 - o timbered back paddock (eradicate the new weed infestation and change to light grazing in autumn–winter only to enable grazing-sensitive wildflowers to reproduce, or cease grazing where appropriate)
 - o whole farm (establish windbreak of native shrubs or trees as habitat for beneficial insects, as a carbon sink and as a wildlife corridor)
 - o district (start a landcare group to help look after the travelling stock route that bisects the area)
- Be pragmatic about your own and others' biodiversity knowledge: question everything, especially assumptions; don't be afraid to go against accepted wisdom when you have evidence to the contrary; base management on existing knowledge, but be cautious and learn from every action.

In addition to these matrix issues is the question of the interconnections between matrix and remnant – neither can be managed in isolation from the other. Without careful consideration of both, and especially of the way management of one impacts on the other, native biodiversity will not be sustained in agricultural landscapes to the extent possible.



Many native species of wildlife exploit the agricultural matrix. (Photo: Lydia Paton)

Conclusions

The agricultural matrix is fundamentally important to the conservation of native biodiversity because many native plants and animal species live their entire lives and successfully reproduce in farmland habitats, many more require the matrix for specific resources or safe passage between native vegetation remnants, and because what happens in farmland affects the biota confined to non-farm habitats. The native plants and animals in farmland are usually a limited subset of the biota that occurred in the pre-existing native vegetation or wetland habitats and sometimes a novel suite of species. Some are declining and need to be managed. The native biodiversity in farmland has value, complementing the biota confined to remnant native vegetation, and with a little effort, could be more diverse and valuable. The novel and synthetic biological communities found across agricultural districts often have a large complement of introduced plants and animals. Indeed, the native vegetation estate and natural wetlands have been infiltrated with all manner of biological invaders, so even high conservation value communities are novel, steadily changing mixes. Intriguingly, synthetic habitats such as tree plantations, irrigation water storages and grazed temperate pastures sometimes approach native vegetation and natural

wetlands in value as wildlife habitat and can provide superior habitat for species at risk, through no intent on the part of management. Therefore, with greater attention to the design, management and ecological understanding of agricultural land as wildlife habitat, the value of the matrix for native biodiversity conservation will increase.

Debates over wildlife-friendly farming versus land sparing as alternative strategies to wildlife conservation on farms miss the point that the entire agricultural estate, both the intensively and extensively managed parts, have value for native biota. With a little thought and some deliberative management, although not necessarily at any additional cost to producers, these values could be realised. An education and awareness-raising program is required to raise the profile of farmland as habitat for native biodiversity and the value of the management services provided by farmers to society. Collaborative research with farmers to understand how the value of farmland for native plants and animals can be sustained and improved for future generations is also required. One likely approach to better managing native biodiversity in the agricultural matrix will be engineering a latticework or scatter of wildlife-friendly habitats, including individual trees, across farmland to improve habitat connectivity.

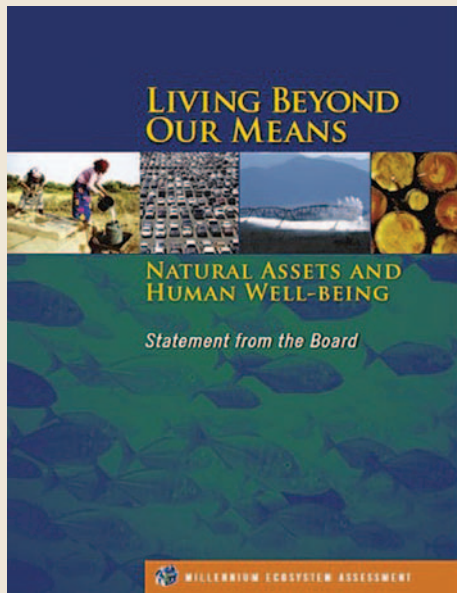
6

ULTIMATE DRIVERS OF BIODIVERSITY CHANGE IN AGRICULTURAL SYSTEMS

In developing strategies for sustaining native biodiversity in agricultural landscapes, it is important to identify and understand the drivers that currently shape both biodiversity and land-use practice,¹⁵⁴ and that determine what can realistically be achieved for biodiversity conservation in these environments in the future. The importance of anthropogenic drivers of change for predicting current and future ecosystem condition was strongly emphasised in the Millennium Ecosystem Assessment.¹⁵⁵ Drivers are defined as any natural or human-induced factors that directly or

indirectly cause ecosystem change. This definition can equally be applied to the factors driving biodiversity change in agricultural ecosystems, including both proximate drivers that result in actual change on the ground and ultimate drivers that underlie these. Our focus here on ultimate drivers is motivated not by an intent to deny the obvious importance of proximate causes of change (vegetation clearance, cultivation, grazing or plantation establishment), but by a desire to better understand the underlying or ultimate influences leading to a farmer's day-to-day management decisions and hence the proximate causes. Notwithstanding this, it is important to acknowledge that human population growth underlies all of these drivers to a greater or lesser extent.

The distribution of biodiversity in agricultural ecosystems reflects the interactions between the underlying environment (climate, landform, soils, etc.) and the effects of human activities (habitat creation, modification and loss, introduction of agricultural and commensal species, etc.). The legacies of these historical influences on biodiversity, together with a range of new, primarily anthropogenic drivers, shape biodiversity patterns in agricultural ecosystems both directly and indirectly: directly, through their influence on biodiversity (e.g. land clearance or invasive species), but most often indirectly (e.g. global economic conditions) through their influence on land and water management practices (e.g. the intensity of management inputs), which in turn have direct effects on biodiversity.¹⁵⁷ The various drivers interact across spatial and temporal scales and can work synergistically, and it is often the synergistic effects that are of most concern for biodiversity conservation.¹⁵⁸

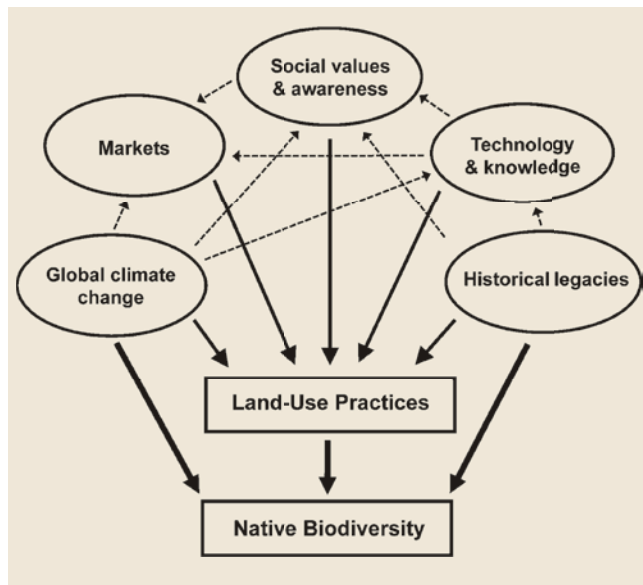


The 2005 United Nation's Millennium Ecosystem Assessment report was the first comprehensive international assessment showing the many and varied linkages between the state of the biosphere and human well-being.¹⁵⁶



What direct and indirect influences convince a landholder to establish native species along a fence line in a highly productive Canterbury Plains mixed cropping-grazing farmscape?

In this chapter, we outline a framework for considering ultimate drivers of biodiversity change in agricultural landscapes. These ultimate drivers of change can be



Relationships between different drivers of change and native biodiversity. While all drivers indirectly affect biodiversity through their effect on land-use practices (thin black lines), only global climate change and historical legacies directly affect biodiversity (thick black lines). Interactions (dotted lines) also occur among the different drivers.

summarised under five broad categories: (1) historical legacies, (2) global climate change, (3) technology and knowledge, (4) markets, and (5) social values and awareness. While global climate change and historical legacies can directly affect native biodiversity, all five indirectly affect biodiversity by influencing the decisions that land managers make about the way they use their land and water resources. These land management decisions have a range of critical flow-on effects for biodiversity. We use examples from Australia and New Zealand to illustrate these drivers of biodiversity change, but similar examples could be found for any agricultural system worldwide.

These five groups of drivers reflect the influence of past conditions (historical legacies), current conditions (markets, technology and knowledge, social values and awareness) and future conditions (technology and knowledge, social values and awareness, global climate change) on biodiversity. Not all changes due to agricultural management are negative for native biodiversity. Some species prosper in the agricultural matrix, and remnants of former communities are often left in transformed landscapes. These positive outcomes for biodiversity conservation need to be recognised.



Red-rumped parrots have done well out of agricultural and urban development in south-eastern Australia. (Photo: Lynn Pedler)

Notwithstanding this, the direct effects of global climate change and historical legacies in particular are more likely than not to be negative for native biodiversity.¹⁵⁹ However, the way that land managers respond to the different drivers in terms of their on-farm management can be modified through the use of incentives and other policies so that the results for biodiversity conservation are positive (see Chapter 12).

The framework presented here provides a starting point for developing an understanding of the complex of factors that are likely to shape options for future biodiversity conservation in agricultural landscapes. Without a clear understanding of drivers of land-use (and hence biodiversity) change, it is not possible to identify and implement appropriate strategies for biodiversity conservation, strategies that are urgently required if biodiversity decline is to be reversed over the majority of the Earth's surface.¹⁶⁰

Historical legacies

Many events that have occurred in the past have ongoing influences on both land management practices and biodiversity today and into the future. Three types of historical legacy are important drivers of change in agricultural landscapes, and especially of the native

biodiversity that occurs there today and into the future: (1) effects of past land management on soils (e.g. erosion, salinisation, compaction, acidification, nutrient decline, seed-bank loss); (2) ongoing adjustment of the remaining biota to historical fragmentation; and (3) the increasing impacts of invasive species already present but yet to realise their full potential.

In some agricultural landscapes, periods of intensive land use (e.g. irrigation or fertiliser application) have resulted in fundamental changes in ecosystem attributes, especially in relation to the soil (e.g. through salinisation). These changes have pushed ecosystems across thresholds of change that may take decades or longer to reverse, or that are irreversible without significant (often prohibitively expensive) management inputs.¹⁶¹ The effects of these changes will influence land management practices and biodiversity for the foreseeable future.

A good example of an historical legacy having a long-term effect on both agricultural production and biodiversity is the influence of phosphorus fertiliser and exotic legume seed inputs in tableland pastures in south-eastern Australia. Elevated soil phosphorus and nitrogen levels, coupled with clearance of timber, resulted in epidemic levels of native scarabs, particularly Christmas



Coolatai grass, a native of Africa, the Mediterranean and Middle East, has expanded aggressively on both public and private land through northern NSW in the past two decades, and continues to spread unchecked.



Christmas beetles devouring the foliage of a white gum sapling (inset) and eucalypt dieback, New England Tablelands.

beetles. Herbivorous beetles, in concert with a wide variety of other defoliating insects, caused widespread dieback of pasture eucalypts, and continue to hamper establishment of eucalypts in intensively developed pasture land.¹⁶² While elevated soil phosphorus and nitrogen are good for grass growth and the loss of dense tree cover has resulted in increased stocking rates, the loss of shade and shelter increases sheep mortality in cold weather, and the loss of scattered trees has caused reductions in native birds, mammals (microbats and arboreal marsupials) and lizards.

Remnant biotas are still adjusting to the effects of fragmentation and the extinction debt associated with past and current habitat loss.¹⁶³ For many species, especially forest species, the conditions that occur after fragmentation reduce the quality of the habitat as edge effects alter forest interior microclimates (e.g. making them warmer, windier and dryer).¹⁶⁴ Both fragmentation itself and management practices on adjacent agricultural land can alter the disturbances that naturally occurred in these systems (e.g. fire or flooding regimes) or introduce new disturbances such as grazing, chemical drift and

weeds, which affect the remnant biota.¹⁶⁵ Habitat loss also reduces the number of remaining individuals of species, increasing their vulnerability to disturbance and the likelihood of local extinction.



Remnant Canterbury podocarp forest that has been strongly affected by grazing and hydrological changes (note ditch around remnant edge). It is unlikely that the native biota has yet adjusted to these changes.

For many species in fragmented landscapes, their local extinction in a patch cannot be reversed by recolonisation from an adjacent area, as propagule sources are absent or too distant. In some cases, especially with plants, species might persist in an area because of their longevity, but have no hope of producing offspring. An extreme example of this is the New Zealand conifer, rimu, a widespread emergent tree of lowland forests. On Banks Peninsula, where this tree appears to have been naturally rare, only two individuals remained after the extreme forest loss associated with European settlement in the late 19th century.¹⁶⁶ Both trees have survived to the present day, but both are male. At some stage, this species will be lost from Banks Peninsula.

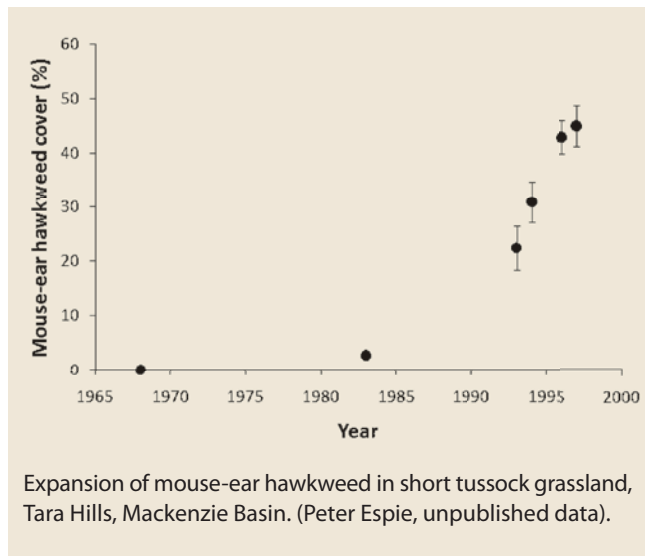
The third area where historical legacies have the potential to drive future biodiversity condition relates to the vast pool of introduced species, especially plants, that occur in gardens or as wild individuals but as yet have no obvious impact on either agriculture or biodiversity. These species may never be a problem, but equally, should environmental conditions or land management

practices change, or if they simply cross an abundance threshold, they could quickly convert from being ‘sleepers’ to ‘invasives’, exerting a significant impact. The sleeper period during which an introduced species is present but only at very low numbers is referred to as the lag phase. Little is known about what triggers a species to move from this phase and expand exponentially, but it is clear that for many species the lag phase can last years or decades.¹⁶⁷ It is difficult to predict when or why a species starts to rapidly expand or even which species are presently sleepers.

The European daisy, mouse-ear hawkweed, is a major pest in the rain-shadow mountains of New Zealand’s eastern South Island. It has invaded short tussock grasslands where it significantly reduces both livestock feed and biodiversity values through outcompeting other plant species for water and nutrients.¹⁶⁸ While it was in New Zealand as early as 1878 (it most likely arrived from Europe as a contaminant in grass seed), it wasn’t recognised as a problem until the 1970s when it started to expand exponentially at a wide range of



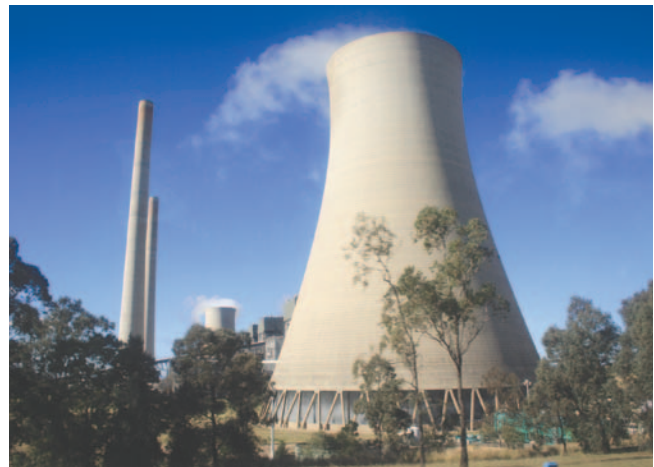
The European weed, mouse-ear hawkweed, has spread rapidly over the past few decades through South Island short tussock grasslands. In much of the Mackenzie Basin, here with Aoraki/Mt Cook in the background, it is now the dominant groundcover.



sites across the eastern South Island. Its expansion appears to have occurred irrespective of domestic grazing pressure,¹⁶⁹ and there is no reason why it will not continue expanding its range and abundance throughout the region. This species is also present in Australian grasslands where it currently occurs at very low densities but has the potential to invade large areas of Tasmania and south-eastern Australia, even under future climate change projections.¹⁷⁰ Species like mouse-ear hawkweed can be present but unrecognised in a flora for many decades before conditions are conducive to their expansion and subsequent impact.

Global climate change

Directly or indirectly, human activities are altering global climatic conditions, shifting the range of conditions away from those that occurred in the recent past.¹⁷¹ While there is much debate about the magnitude of change, and how much of it might be occurring independent of human activities, it is clear that atmospheric chemistry, global climatic conditions, and the distribution of species are changing across the planet with both direct and indirect effects on biodiversity. While climate change is only one of a range of environmental changes that are occurring globally (others include nitrogen deposition, land-use change, biotic invasion and CO₂ enrichment), we focus specifically on climate change here because of its dominant influence on both agriculture and biodiversity. We see land-use change as one of the proximate causes of biodiversity change while biotic invasion was discussed under historical legacies.



Coal-fired power stations are a major source of greenhouse gas emissions in the modern world.

Global climate change is challenging farmers as they cope with changing weather patterns. While the long-term consequences of climate change will be shifts in average rainfall and temperature patterns, it is the changes in the frequency and intensity of extreme events such as droughts, floods or frosts that are likely to be most significant for both farm production and biodiversity in agricultural landscapes in the short to medium term.¹⁷² Farmers already have to deal with more unreliable weather events. For example, the millennium drought in eastern Australia was the worst drought on record and elevated temperatures resulting from CO₂ enrichment probably exacerbated its effects. An increased incidence of unusually severe flood events, attributed to changes in global circulation patterns bringing more tropical cyclones southwards across New Zealand, has also challenged farmers over the last few years.



Droughts are likely to become more frequent and extreme over the course of the current century under climate change.

Native biodiversity will be affected by global climate change directly through changes in species ranges, including invasive species, and changing interactions between species.¹⁷³ Biodiversity will also be affected indirectly through changing land-use patterns as farmers change their management practices to cope with climate change.¹⁷⁴ While the potential direct effects of climate change on biodiversity are generally well appreciated, the indirect effects are less well understood.

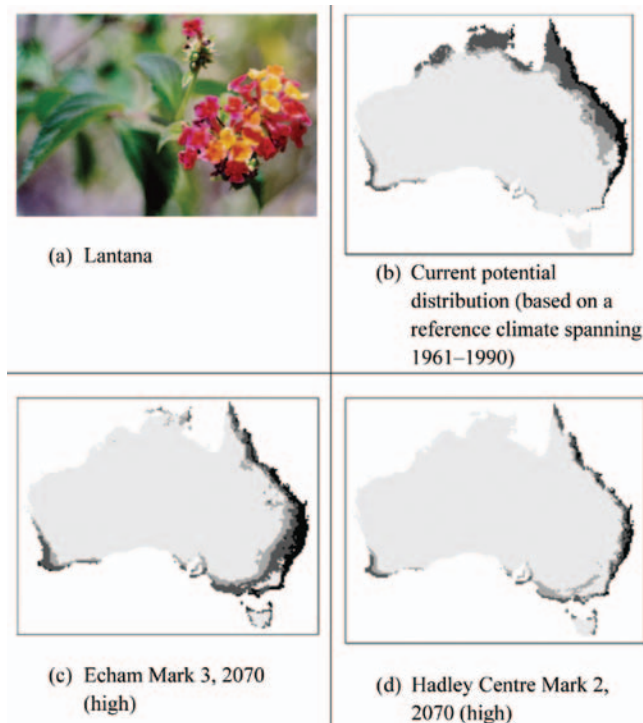
Direct effects will include changes in species ranges as warmth-intolerant and drought-intolerant species are unable to cope with emerging conditions. The effects of changing weather patterns are likely to be exacerbated by the fragmented nature of much of the remnant biodiversity in agricultural landscapes, with remnant areas already under stress from edge effects, altered disturbance regimes, small population sizes and lack of connectivity. Climate change is likely to push species already on the brink of extinction over the edge. For example, significant elements of the Australian Alps fauna is already declining as a result of habitat loss, with climate change likely to push some species to extinction (e.g. corroboree frog).¹⁷⁵ Furthermore, climate change is facilitating the expansion of invasive plant and animal pests into new areas that were previously unsuitable, as changing conditions increasingly favour them. As a result, competitive interactions between species (native–native, native–exotic and exotic–exotic) are likely to change, with flow-on effects for biodiversity. The southward spread of species such as banana passion vine and common myna in New Zealand and lantana in Australia is likely due to changing climatic conditions.

Global climate change will also affect biodiversity through intensification of farm management practices as farmers seek to buffer themselves against the vagaries of unpredictable weather. In New Zealand, irrigation is being increasingly used to guarantee grass and crop growth as summer droughts become more frequent, while new grass and legume cultivars and species are being used to better buffer dryland systems. For example, a succession of below-average annual rainfall years since 2000 in the Mackenzie Basin has increased pressure on farmers to establish irrigation or plant legume crops such as lucerne. Intensification has a number of flow-on effects for biodiversity, whether as a result of habitat loss as remnant vegetation is cleared to accommodate more

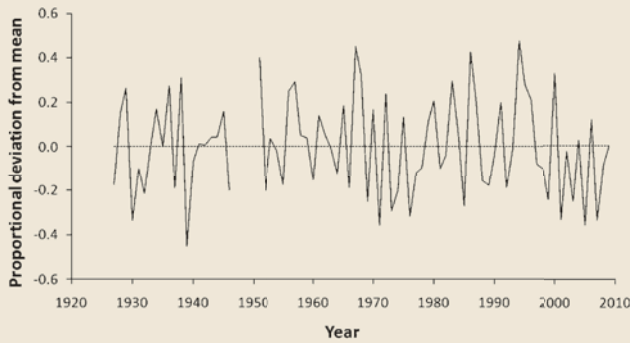
intensive farming systems, or through flow-on effects to other parts of the ecosystem (e.g. eutrophication of waterways as a result of increased fertiliser inputs and irrigation, or altered river flows as a result of abstraction and regulation).¹⁷⁶



Banana passion vine fruit and flowers, an invasive plant likely to benefit from climate change.



Current (top right) and projected (bottom) distribution of lantana in Australia under two 2070 climate change projections. The current potential distribution is based on the climatic tolerances of the species given a reference climate averaged over the period 1961–1990. The projected distributions are based on modelled climates for 2070 using the Echam Mark 3 and Hadley Centre Mark 2 models assuming high-emissions scenarios to 2070 (Subhashni Taylor, unpublished data). (Photo: Jason Cummings)



Annual rainfall series, Lake Tekapo, Mackenzie Basin, 1927–2009. Data are expressed as proportional deviance from the 1927–2009 average value. Note the unusually high incidence of below average rainfall years since 2000.¹⁷⁷

Technology and knowledge

Technology and knowledge are major drivers of change in farming systems. The availability of new technology has revolutionised agriculture over the last 50 years, especially the development of synthetic fertilisers, new genotypes and the incorporation of genetic engineering technology to increase disease resistance and productivity and facilitate weed control.¹⁷⁸ The development of larger, more powerful machinery, the use of new herbicides and

pesticides, and more recently the application of spatial information technology, have also been revolutionary in enabling farmers to produce more food and fibre at lower cost, and to move into environments that previously were not able to be farmed (e.g. the heavy soils on alluvial floodplains that early post-war machinery could not cultivate).

Technology can be both positive and negative for biodiversity: positive in that many of the new technological advances have enabled farmers to better target management interventions, thus sparing areas with biodiversity values (e.g. through the use of GPS to guide application of fertiliser or herbicide) and in being able to increase productivity in one part of the farm and spare or rest other areas. Technological advances have also enabled the application of more environmentally sustainable management practices such as direct drilling as opposed to ploughing. However, the advent of new technology has also enabled farmers to farm new areas, especially areas that might otherwise have been marginal or too difficult to crop (e.g. through using genetically modified crops tolerant of more demanding conditions), and to increase the size of individual management units (e.g. paddocks) and farms in order to capitalise



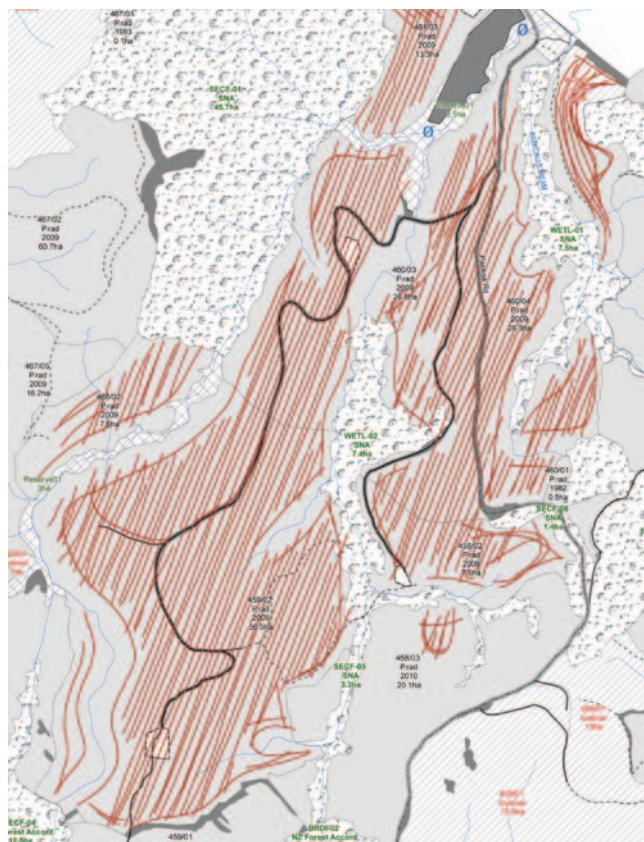
With the advent of larger, more powerful tractors regular cultivation of the heavy cracking clay soils on floodplains in inland eastern Australia became possible. Zero till is a more recent innovation to preserve soil structure. (Photo: Leah MacKinnon)



Herbicide drift from an irrigated field into adjacent river red gum and cooba vegetation in the Namoi Valley, NSW.

on economies of scale, potentially increasing impacts on biodiversity through increasingly homogenised farmscapes and removal of paddock margin and fence line biodiversity. Some technological advances have been both positive and negative. For example, direct drilling enhances soil condition by removing the need for ploughing, but the increased use of herbicides and spray drift may affect adjacent native ecosystems. The key point is that biodiversity needs to be considered explicitly in the development of new technology to avoid the mistakes of the past.

Knowledge is a key driver of change in farming systems, both in relation to farming practices and in relation to biodiversity. Knowledge feeds into social values and awareness (next section) as well as having a direct impact on the way land is managed and hence on biodiversity. Much of the impact of past agricultural practices on biodiversity has occurred because farmers (and land managers more generally) have not had the relevant information to enable them to realise the adverse consequences of their activities. The introduction of mustelids such as stoats into New Zealand to control plagues of rabbits illustrates this well. We now appreciate the inherent folly of such introductions, but



GPS tracking of helicopter herbicide operation (red lines) associated with plantation forest establishment that avoided native forest remnants (stippled areas). (Image: Kit Richards)



More ecological research in the agricultural matrix is required to understand how best to conserve native biodiversity to assist primary production and human well-being and for future generations. (Photo courtesy of Chris Carr)

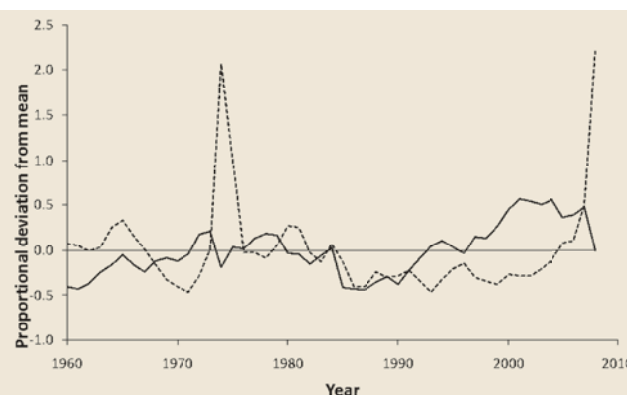
the knowledge was not available in the late 19th century when they were introduced. Because the recognition of the importance of biodiversity conservation in agricultural landscapes is relatively recent, there is a dearth of knowledge about the issue. Several studies have highlighted the lack of ecological research undertaken in agricultural landscapes.¹⁷⁹ For example, a survey of New Zealand ecological literature published between 1968 and 1997 found that 65% of articles focused exclusively on protected areas while 18% concerned non-protected areas (mainly agriculture and plantation forests), despite production landscapes accounting for nearly 70% of the total land area at that time.¹⁸⁰

Markets

The international marketplace is a major driver of agricultural decision making, and hence of change in native biodiversity. In countries like Australia and New Zealand, farmers are exposed to the vagaries of international markets including the price of farm inputs (especially fuel and fertiliser), changing consumer preferences and demands, the availability of substitutes (e.g. synthetics for natural fibres) and cheap imports, and the effects of the global economy (cycles of recessions and booms). The effects of these can be both positive and negative for biodiversity. Farmers benefit from the increasing demand for primary produce, access to new markets through trade liberalisation, superior product quality and increasing sales of 'green' products, but are susceptible to the increasing cost of key inputs and

competition with food and fibre products from countries with lower cost structures. Market drivers do not have a direct effect on biodiversity, but have three consequences that can have profound flow-on effects for biodiversity: (1) changes in the type of farming operation that is undertaken (e.g. shifting from a less profitable to a more profitable operation); (2) changes in the profitability of the farming operation itself, thus affecting what the farmer can afford to do; and (3) changes in the tax take, which in turn affects the funds available from local, state and national governments for conservation work on both public and private lands (including stewardship and compensation payments). The internationalisation of farming has also meant that there is less incentive to utilise local plants for agriculture – production of grass and legume seed is largely dominated by multinational corporations with little opportunity for local producers to compete using local seed sources that would help to sustain local biodiversity.

One of the key causes of increased agricultural production over the last 50 years has been the increased use of fertiliser, especially nitrogen-based fertilisers.¹⁸¹ Fertiliser production is dependent on both supply (especially for fertilisers based on mining naturally occurring deposits, such as phosphorus) and the energy costs of fertiliser production. Spikes in global fertiliser prices in the 1970s and 2000s led to rapid reductions in fertiliser application as farmers accepted reduced productivity gains in the face of the increased cost of



Global fertiliser price standardised to US\$ prices in 2000 (----) and fertiliser use in New Zealand (—). Values are expressed as a proportional deviance from the 1960–2009 average values. Marked increases in price in the mid 1970s and again in the late 2000s resulted in sharp drops in fertiliser use.

fertiliser. Flow-on effects to biodiversity are complex. Cheap fertiliser enables farmers to intensify their management with high impacts on biodiversity. However, high fertiliser prices force farmers to use less fertiliser, perhaps leading to the increased use of marginal lands to counter the loss in productivity from reduced fertiliser application on their better land, thus also impacting on biodiversity.

The increasing demand for meat and milk products in 'emerging' economies is going to be a major driver of agricultural change into the future. Consumer preferences and demands can be important drivers of land-use change. Demand for natural fibres over high-energy artificial fibres (polyesters) and a more general desire for 'green' food products can be positive for biodiversity if land managers are required to meet environmental management standards (e.g. relating to biodiversity, carbon and water). A key challenge for Australia and New Zealand is to decide if our agricultural products will be targeted at higher value markets in Europe and North America that are dominated by more discerning and environmentally aware consumers, or at lower value commodity markets in Asia where environmental considerations are likely to be less pressing. However, even in environmentally aware markets, unanticipated outcomes can occur – for example, consumer concerns over animal welfare issues are driving the cessation of mulesing of sheep but may result in an increase in the use of chemicals to control flystrike. Long term, one of the potentially biggest drivers of biodiversity change may be the peak and subsequent decline in petroleum production and the effect it will have on farm management globally.¹⁸² While this may result in a decrease in the intensity of cultivation, it may well result in an increase in the area under cultivation with subsequent impacts on biodiversity.

All of these factors affect biodiversity by changing the nature of agricultural activities. They can also reduce resource availability for desirable but lower priority activities by landowners, local authorities and central government, such as nature conservation. Changing attitudes towards indigenous biodiversity may increase or decrease interest in non-economic values: certification may lead to positive changes in attitude, but if farm profits decline, a farmer's ability to pursue discretionary stewardship activities and expenditure may also be reduced.



Attitudes towards native plants and animals have varied widely over the past three centuries, and will help determine the future of native biodiversity.

Social values and awareness

The way we value biodiversity and agriculture has a fundamentally important influence on what happens to native biodiversity in agricultural landscapes. This is particularly evident in the way in which society's valuing of agricultural production versus biodiversity conservation has changed through time. Value systems affect biodiversity both through the legal and policy environments that reflect the social values of the time and through the awareness and attitudes of people (urban and rural) towards native biodiversity.

When European settlers first colonised Australia and New Zealand, elements of the native biodiversity were seen as a hindrance to 'good' land management.¹⁸³ The new settlers struggled to understand the local environment and land management approaches were biased by the European agricultural tradition and 'what worked best'. During the early settlement period most people worked directly on the land or were dependent on agriculture for their income. Few people at that time believed that native ecosystems, especially timbered areas, held any value beyond that of the timber and grass they supported, or the land on which they grew. In fact, forests, woodlands and mallee were widely seen as a hindrance to progress. Settlers actively sought to impose a European mantle across the land by clearing timber, planting pastures and crops from the northern hemisphere, and introducing livestock. Government policy at the time actively promoted this through setting land improvement requirements that needed

to be met before land ownership could be gained (e.g. the *Robertson Crown Lands Acts 1861* in NSW). Links between woodland and forest cover, and soil and water values were not appreciated, while livestock numbers in both Australian and New Zealand rangelands reached densities never matched subsequently as flocks and herds bred up in good seasons and consumed all the available forage in difficult years, degrading the land.¹⁸⁴

Not only were exotic species seen as necessary to establish a viable farming sector, they were also seen as having many excellent qualities that would enhance other values. For example, in New Zealand, trout provided opportunities for fishing that were lacking, red deer and other ungulates filled an apparently ‘vacant niche’ in a country that lacked flightless mammals, while heather was seen as providing habitat for grouse, although the latter were never successfully introduced. In 1867, the New Zealand Colonial Parliament passed legislation to provide for the protection of certain animals and for the encouragement of acclimatisation societies in New Zealand. This Act gave formal legislative support for the introduction of exotic species, which the acclimatisation societies actively implemented. Acclimatisation societies were also active in Australia at this time. In Melbourne,

the Acclimatization Society of Victoria was formed in 1861 with the principal objective of ‘the introduction, acclimatization and domestication of all innoxious [i.e. harmless] animals, birds, fishes, insects and vegetables whether useful or ornamental.’¹⁸⁵ European rabbits and foxes were introduced for sport. In fact, there was a widespread perception among 19th century naturalists that exotic species would supplant the indigenous flora because of their ecological superiority. For example, Charles Darwin wrote in 1859 that:

‘... from the extraordinary manner in which European productions have recently spread over New Zealand, and have seized on places which must have been previously occupied, we may believe, if all the animals and plants of Great Britain were set free in New Zealand, that in the course of time a multitude of British forms would become thoroughly naturalised there, and would exterminate many of the natives.’

Values and awareness have, however, changed over time. In Australia, aridity, frequent drought and poor soils made it difficult to impose the traditional European agricultural model over most of the continent, while in New Zealand, the lack of trees resulted in severe soil



Red deer were introduced to New Zealand in the 19th century and quickly spread. Today they are officially a noxious pest on public land but are highly valued by trophy hunters and managed for both venison and hunting on high country farms.



Thomas Austin is credited with allowing rabbits to run wild across mainland Australia by releasing them at Barwon Park near Winchelsea, Victoria, in 1859. He allegedly wrote 'The introduction of a few rabbits could do little harm and might provide a touch of home, in addition to a spot of hunting'. The red fox was introduced to Australia for hunting near Melbourne some 16 years earlier. Both species have had a huge environmental and socio-economic impact subsequently. (Photo: Lucy and Rob Adams)

erosion and loss of productive potential of the land that farmers sought to utilise. Soil and water conservation became both desired and necessary and new land management practices were developed to cope with the profound changes that resulted from European-style farming. Contour banking of sloping croplands in Australia and tree planting with exotic species in New Zealand were undertaken to reduce soil erosion.

More recently, most people have begun to appreciate the intrinsic value of native biodiversity in addition to its utilitarian values for agriculture (e.g. for grazing and natural pest control) and forestry, or its provision of ecosystem services such as clean water and pleasant landscapes. Although dating back to the late 19th century, the expansion of the national park and reserve systems in the latter decades of the 20th century, together with greater questioning of conventional farming practices, reflect these changing perspectives. These changing values have been strongly influenced by the overwhelming dominance of urban populations that developed in the second half of the 20th century,

with 89% of Australians and 86% of New Zealanders now living in urban areas. The urban population, and by default the politicians that represent them, often have a very different awareness and values to many rural populations.



Recently burnt forest, Banks Peninsula, late 19th century. The men in the foreground were employed to sow cocksfoot seed on the recently burnt land. (Image courtesy Canterbury Museum)



Water spreading banks hold up water on the uphill (left-hand) side, release it through gaps in the bank to pond in the borrow pit on the downhill side, and then release it along the length of the borrow pit, thereby slowing runoff and enhancing infiltration in arid rangeland in western NSW.

Conclusion

An appreciation of the drivers of biodiversity change in agricultural ecosystems is important, as it enables us to better develop policies and plan management activities in order to achieve desired outcomes. Distinguishing between direct and indirect drivers is particularly important, as it is the indirect or ultimate drivers that are perhaps likely to have the greatest influence on future biodiversity given that the primary use of farmland is for food and fibre production. The drivers discussed here substantially impact on native biodiversity, both directly but especially through their strong influence on

farm management practices. These in turn dictate the nature and habitat qualities of the production matrix and shift remnants of native ecosystems into structural and compositional states further from their historical condition.¹⁸⁶ These changes are likely to require novel approaches for the long-term management of remnants¹⁸⁷ as well as explicit consideration of the value of the passing parade of farm enterprises in the agricultural matrix for native biodiversity, approaches that need to be recognised and incorporated in farm-scale biodiversity planning.

7

INTRODUCTION TO CASE STUDIES

In this second part of the book we present a series of case studies of biodiversity conservation approaches and initiatives within working farms. There is an amazing amount of active conservation management going on throughout rural Australia and New Zealand, much of it funded by landowners and local communities, and most of it unrecognised by the wider population.

We have divided the case studies into three themes:

- Programs and approaches facilitating biodiversity
- Approaches to managing biodiversity on the ground
- Property case studies.

These three themes make a convenient framework within which to look at the different types of biodiversity management that is occurring in farming systems. The case studies we have included are only a small sample of what is happening in rural Australia and New Zealand and it is important to acknowledge that there are many other equally exciting initiatives resulting in positive outcomes for biodiversity conservation. Our case studies reflect, to a large degree, the systems and regions that we are most familiar with. Notwithstanding this we believe that the approaches outlined in these case studies may well be applicable more widely, although it is important to emphasise that no one approach will work in all or even most situations. The nature of the environment and hence of the farming systems and the biodiversity that occurs within them is incredibly diverse, individual farmers have different preferences, attitudes and desires, while local socio-economic conditions might allow one approach to work in one area but not in another.

We see these case studies as serving two main functions. First they emphasise just how much biodiversity

conservation is already occurring in rural Australia and New Zealand and showcase the individual farmers and others who are behind them. Most importantly, these case studies come from working farms and it is often these farms that are the most financially successful in their region – highlighting the ‘win-win’ outcomes that are possible. Secondly, we hope that the case studies are inspirational and provide others with ideas and motivation to undertake biodiversity initiatives on their own properties or in their own communities. We hope that farmers and others will be inspired by these examples to develop their own solutions for their situations.

References to more detailed information on the approaches taken are, where appropriate, given in some of the case studies, but more often than not excellent information can be found on the websites of the key groups involved in biodiversity management on private land including non-government¹⁸⁸ and government organisations.¹⁸⁹



Beef cattle with a regenerating shrubland of native and exotic species behind.

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8

PROGRAMS AND APPROACHES FOR BIODIVERSITY CONSERVATION

This first set of case studies focuses on some of the policy programs and approaches that are being implemented or could be implemented in rural Australia and New Zealand. While the traditional approach towards biodiversity conservation on private land has been regulatory, more often than not involving the imposition of constraints on land management by a government agency, we have focused on the rapidly developing array of non-regulatory approaches that have been emerging in recent years.

Regulatory approaches have typically failed to win widespread support from rural communities as well illustrated by the NSW experience with *State Environmental Planning Policy 46* and the subsequent *Native Vegetation Conservation Act 1997*. However, alternative approaches have been rapidly developing and focus on a mix of voluntary and market-based

approaches towards achieving biodiversity outcomes within farming environments and rural communities. In addition, there has been increasing emphasis on investing in knowledge and education among rural communities, which has been critical in empowering them to undertake conservation initiatives on their own accord (and without top-down regulatory control).

In this section we review some of these new approaches in order to highlight some of the options available for farmers wishing to engage in biodiversity conservation, and highlight many of the potential advantages to farmers of these approaches. We also profile two scientists who have played key roles in making biodiversity conservation more readily accessible to rural families. The case studies covered here are not exhaustive but provide a good overview of the range of approaches available.



Various approaches are available for sustaining native biodiversity in South Island high country farming systems.
(Photo: Angus McIntosh)

Australian government's Environmental Stewardship Program

Environmental Stewardship was introduced in 2008 as part of the Australian government's flagship program, Caring for our Country, which aims to sustain the Australian environment. The Environmental Stewardship Program involves the commonwealth contracting and paying landowners to protect and manage biodiversity assets of national environmental significance on private land. To date, the program has been rolled out in Queensland, New South Wales and South Australia, and is focused on five ecological communities listed as endangered or critically endangered under the federal *Environment Protection and Biodiversity Conservation Act 1999*: box–gum grassy woodland in NSW and Queensland; basalt and alluvial natural grasslands, and weeping myall woodland in NSW; and peppermint box grassy woodland and hard mat-rush temperate grasslands in SA.

The Environmental Stewardship Program has been structured to achieve several objectives related to the ecological importance of remnant vegetation on private land, the extent and quality of vegetation, the level of the

threat or risk that an area is subject to, the ability of the landowner to manage the risk, and the commonwealth's environmental and economic return on investment. A 'reverse auction' system has been devised that allows landowners to bid for a contract with the government to manage and conserve an area of an endangered community on their land. The commonwealth contracts a service provider to liaise with landowners in the relevant regions in which the endangered communities occur and to help interested landowners put together their bids. The landowner indicates in their bid how much money they are seeking in return for a set of mandatory and discretionary management services they offer in return. Each area that is the subject of a bid is assessed in terms of its biodiversity values and the likely improvement in biodiversity values over the term of the contract (maximum 15 years). The commonwealth ranks all the bids in terms of biodiversity value and expected improvement in value, the likelihood that the area will be maintained in good condition in perpetuity, and the amount of money sought by the owner.



Box–gum grassy woodland in northern NSW.



Weeping myall woodland near Bellata, NSW, is one of the threatened communities targeted by the Environmental Stewardship Program.



Flowering creamy candles in hard mat-rush (iron-grass) temperate grassland in the Mid North of SA.



Native oatgrass and native millet dominating alluvial grassland near Gurley, NSW.

To date, there have been several iterations of the program. The first rollouts focused on just box-gum grassy woodland remnants in NSW and Queensland, and management services provided by landowners just within the contracted area of the listed community. The most recent rollout has expanded the program to encompass all five endangered communities mentioned above, and considers management activities on adjacent land that are designed to protect or improve the conservation value of the endangered community.

To October 2010, landowners had been contracted to manage more than 26 000 ha of box-gum grassy woodland in NSW and Queensland for up to 15 years under the program.¹⁹⁰ \$70.5 million had been spent on the program, of which administration costs (including staff salaries, consultant fees, delivery agents' costs, and monitoring and evaluation) were 10.3% of total funds. The average annual cost for the box-gum grassy woodland project was \$202 per hectare per year, with significant variation within and between regions. Landowners had the option of agreeing to a covenant

over the land to secure conservation management in perpetuity. Comparison of all 15-year agreements for the box-gum grassy woodland project indicated that the additional payment to landowners for agreements that included a covenant was \$1120 per hectare, and covered about a quarter of the area of box-gum grassy woodland in the program. An independent review of Environmental Stewardship by Marsden Jacobs Associates broadly endorsed the program's objectives, procedures and administration.

In 2011, management agreements had been negotiated over another 20 000 ha across all five threatened communities across three states. The federal government also agreed to extend the funding for Environmental Stewardship for a further 4 years.

It is too early to say what the biodiversity outcomes have been of this innovative and ambitious conservation program. However, it is possible that the program will be broadened to other assets of national environmental significance in due course, such as other threatened ecological communities and threatened species.

Biodiversity offsetting

The bottom line for every farmer is the need to be economically viable – farmers who are unable to maintain a positive financial balance sheet are not able to invest in biodiversity management. One of the most common options for many farmers facing the ever increasing costs of farm inputs, such as fuel, fertiliser and water, is to increase productivity through management intensification. Traditional farm development has typically involved clearing of woody vegetation to increase the amount of herbaceous biomass and cultivation of low-productivity systems in order to establish more productive species such as fast growing grasses and legumes. In these cases, farm development is usually seen as inimical to biodiversity conservation – it is not possible to clear or cultivate without having direct impacts on the biodiversity present. However, farm development and biodiversity conservation need not be mutually exclusive if the concept of biodiversity offsets¹⁹¹ is included as part of the development model.

Biodiversity offsets are based around the notion that intensive development on one part of the farm can be traded for more permanent protection or sustainable management of biodiversity on another part. For example, a property that includes large areas of native vegetation that has been badly overgrazed, might trade off the clearing or conversion and management intensification of part of this area, by reducing or removing grazing and implementing restoration policies on another part. Underlying this trade-off is the notion that the economic benefits from development will outweigh the opportunity cost of managing the offset for conservation. This should result in a ‘win-win’ outcome for both the economic viability of the farm and for biodiversity conservation. The following example is for a biodiversity offset associated with farm development in New Zealand.

Waikatea Station (3570 ha) is a typical eastern North Island hill-country sheep and beef property. The



Intensive development of part of this property (foreground) has enabled the surrounding hill country to be retired from grazing and now managed for native biodiversity through the active control of weeds and animal pests, Otago.



Regenerating forest with remnant old-growth rimu that was to be fenced and covenanted as part of the Waikatea Station biodiversity offset.



Regenerating forest sprayed for pasture development on Waikatea Station.

topography is generally steep, with sharp hill crests separated by incised rivers. Exotic pasture (grass–clover mix) dominates. However, a little over one-quarter of the property supports native forest and shrubland, much of it of recent origin, having established in areas that were previously under pasture. The dominant forest and shrubland understorey plants are of low palatability, as the native forest and shrubland is heavily grazed during winter when pasture feed is in short supply. The carrying capacity of the forest and shrubland is limited compared to pasture. In order to improve the economic viability of the property the owners sought resource consent from the local council to clear 354 ha of shrubland and low forest for pasture development in return for protecting a further 799 ha of forest and shrubland (the biodiversity offset).¹⁹² By fencing the offset area to exclude domestic livestock and through control of pest animals, regeneration was to occur and the long-term sustainability of these areas ensured. A covenant was also proposed to provide for ‘in-perpetuity’ protection. In return, the cleared forest and shrubland was to be over-sown and fertilised to provide high-yielding exotic pasture. This proposal was accepted by both local government and the New Zealand Environment Court,¹⁹³ although its subsequent implementation has not occurred because of a dispute over the amount of fencing required; so the remnant native forest areas continue to decline.

Similar approaches occur in Australia. For example in coastal and peri-urban areas of NSW, biobanking is being used to manage the impact of vegetation clearance on endangered plant communities. Developers either need to purchase biobank credits prior to clearance, or put in place their own biodiversity offset involving the protection (usually with covenants) and management (establishment of nesting boxes, restoration plantings, etc.) of otherwise unprotected and unmanaged examples of the same plant community. In rural NSW, the *Native Vegetation Act 2003* requires landowners who wish to develop areas of woody regrowth (e.g. through clearing or thinning) to negotiate with the regional catchment management authority an appropriate biodiversity offset, which is likely to involve covenanting in perpetuity part of the regrowth on the property for conservation purposes.

When a formal biobanking system is in place, as is the case in coastal and peri-urban NSW, farmers with key remnants of biodiversity can earn income by selling biobank credits. In this situation, the landowner needs to first have the biodiversity values formally assessed by an accredited assessor who then draws up a biobanking credit agreement, whereby the current values are detailed, the credit amounts to be awarded are listed, and the management actions to maintain these values are stipulated. This agreement is sent to the



Peri-urban and suburban development along the Central Coast of NSW often occurs alongside high-conservation-value native forest containing several species of threatened birds and mammals. Developers are increasingly turning to offsets and biobanking in these situations. (Photo: Phil Conacher)

NSW Office of Environment and Heritage (OEH) for review and approval, and the Biobanking Agreement registered on the property's land title. Credits awarded through this system can then be advertised on the Biobanking Register, which is maintained by OEH, to await a suitable developer to purchase them.

One of the big challenges for implementing biodiversity offsets and biobanking schemes is deciding what is a fair trade from a biodiversity perspective.¹⁹⁴ In Australia, the habitat hectares methodology¹⁹⁵ has been developed as a tool to allow quantification of both the values that will be lost through clearance and the potential gains from the offset. This approach has recently been extended internationally through the Business and Biodiversity Offsets Programme¹⁹⁶ and is being developed further in both Australia and New Zealand. However, while biodiversity offsetting is still in its infancy and is not sufficient in itself for sustaining native biodiversity in farmscapes, it does represent one model that farmers can use to allow for farm development while also enhancing biodiversity values. There is also a need to ensure that the biodiversity outcomes from an offset are sustained

in perpetuity, as the loss of biodiversity that will occur as a result of the development (e.g. native vegetation clearance) will also be in perpetuity. Protective covenants are one tool to achieve this outcome.



Accurately quantifying biodiversity values is essential for ensuring that the biodiversity exchange is fair in an offset.

Managing woody vegetation for carbon credits

The Permanent Forest Sink Initiative (PFSI) is a New Zealand government strategy to promote the establishment of permanent forests on previously unforested land in order to help New Zealand meet its Kyoto Protocol obligations of reducing carbon emissions while also offering landowners the opportunity to earn Kyoto compliant emission units. There are two categories of PFSI forest: plantations established on Kyoto-compliant land after 17 October 2002 and regenerating native forest on land that was not classed as forest on 31 December 1989. This latter class of forest provides substantial opportunities for both biodiversity and economic values on a property, as the landowner can gain an income through selling emission units as carbon is sequestered in the regenerating forest through protecting the regenerating native forest.

To be eligible for consideration as a PFSI regenerating natural forest, the owner needs to be able to show that

the site was not forested on the 31 December 1989 and that it didn't include any potential forest-forming trees, even as regeneration, at that date. Typically an eligible area would have been in pasture in 1989. Landowners then need to be able to show that they have either actively planted the site (e.g. as part of a restoration project) or have actively promoted forest regeneration (e.g. through removing domestic livestock). Determination of carbon sequestration is then based on data for the increase in the total carbon pool (tonnes C/ha) over a commitment period (the first being from 1 January 2008–31 December 2012). The New Zealand Ministry of Primary Industries has developed accounting systems for doing this. Landowners also have to enter into a binding covenant over the PFSI forest that places an obligation on the landowner to refund the government for any reduction in carbon storage (e.g. due to negligence or *force majeure*). Harvesting is restricted for 99 years to <20% of



Valley bottom restoration plantings on a previously pastured site that are earning carbon credits, Northland.



Regenerating native forest represents a potential income source for farmers through carbon credits while also enhancing native biodiversity values, Nelson.



Farm forestry with fast growing radiata pine is one option for farmers to earn carbon credits. Although sequestering carbon at a much faster rate than native regeneration, radiata pine is not as valuable for native biodiversity.

the basal area per hectare, and the lost carbon removed from the accounts. After 99 years harvesting is allowed, but replacement obligations remain for any carbon lost.

Much hill country on New Zealand farms is marginal for pastoral farming because of the cost of spreading fertiliser and seed, and the relatively low productivity even when 'improved'. Much of this land is also very prone to erosion. With the removal of fertiliser subsidies in the 1980s considerable areas of hill country have started reverting through shrubland to native forest, especially where rainfall is reliable and seed sources close. This country is expensive to keep in traditional farming and with the PFSI now implemented, carbon farming is a possible financially viable alternative use for this land. The potential increase in forest cover is substantial. For example, in one 900-ha catchment on Banks Peninsula, the area of native woody vegetation increased from 273 to 356 ha over the period 1985–2005, representing an average increase of about 4 ha per year. This increase occurred under a *status quo* farming model that wasn't actively promoting woody regeneration. Much higher regeneration rates occur when domestic livestock are actively excluded.

Many studies have shown that so long as seed sources are in reasonable proximity and grazing animals are excluded, these regenerating shrublands will develop into mature closed canopy forests able to support the

full range of biodiversity that occurs in comparable forest remnants.¹⁹⁷ From a farmer's perspective this process is long term, with podocarp trees, the canopy dominants over much of lowland New Zealand, taking several hundred years to reach maturity thus ensuring an ongoing carbon income for the foreseeable future. But even better, the regenerating forest is restoring biodiversity into what was once highly degraded pasture, and is also providing other ecosystem services including reduced erosion and enhanced water quality, which will benefit the rest of the farm and society more generally.

Although the PFSI was only legislated in November 2008, several PFSI forests have been registered and credits have now been sold providing an income to farmers. One example is Ararewa Forest in South Taranaki. The 477-ha PFSI forest is split 50:50 between plantation forest (eucalypts and radiata pine) and native forest regeneration. The property comprises steep hill country and the PFSI area was used for cattle and sheep grazing prior to 1990. This was New Zealand's first PFSI-accredited forest and the credits for the first commitment period have now been sold by Permanent Forests International, a company specialising in developing permanent forests for landowners and then brokering the resultant carbon credits to domestic and international buyers.

Grass banking

Grass banking is an exciting initiative being undertaken by a number of NGOs in the United States.¹⁹⁸ The basic premise of a grass bank is that a conservation organisation purchases a farm in an area with key conservation values. As well as undertaking conservation management on the property, grazing is offered at reduced rentals to graziers from nearby properties if in return they implement conservation programs on their own properties. As a result the total area over which conservation outcomes are achieved is much greater than just the area of the grass bank itself. Grass banking has been particularly successful in the extensive prairies of western North America where cattle grazing can be used to mimic historic bison grazing.

One example of a grass bank is The Nature Conservancy's 24 000-ha Matador Ranch on the glaciated plains of northern Montana, USA. The flat to gently undulating prairies of the glaciated plains comprise a mix of native perennial grasses, native herbs

and sagebrush species; trees are restricted to riparian zones. These landscapes were grazed historically by bison and other ungulates (pronghorn, mule deer, elk), but today are dominated by cattle. In pre-European times, bison herds grazed some areas hard while leaving others ungrazed, thus creating considerable habitat heterogeneity and providing habitat for a wide range of birds and other mammals. Natural fires further increased this heterogeneity. In contrast, cattle are usually grazed uniformly across the landscape, with fencing used to control their movement, and fires are actively suppressed thus reducing habitat heterogeneity. Today these grasslands still contain a number of threatened animals including pronghorn, black-tailed prairie dog, black-footed ferret, burrowing owl, long-billed curlew and sage grouse, but all of these species are declining. As well as inappropriate grazing, another key threat to several of these species is 'sod-busting', the conversion of prairie to cultivated fields.



Cattle grazing on the Matador Ranch grass bank, Montana, USA.

Simply retiring land from cattle grazing will not sustain biodiversity values as it is the habitat heterogeneity that results from grazing and fire that is essential for native biodiversity. The Nature Conservancy have taken the approach that in the absence of bison, cattle grazing can be used to sustain biodiversity values. In purchasing Matador Ranch, both the number of cattle grazing the property has been reduced (by 25%) and a more heterogeneous grazing regime has been introduced, better mimicking historic bison grazing. Sod-busting is no longer undertaken, while experimental burns have been introduced. It is planned to burn 10% of the area each year with the goal of further modifying grazing patterns as cattle (and other ungulates) preferentially graze newly burnt areas (resulting in heavy grazing) and avoid unburnt areas (resulting in light grazing).

But more importantly, the establishment of the Matador grass bank has facilitated a range of biodiversity conservation actions on nearby properties through the implementation of a rent reduction program for participating graziers. Rental is initially discounted from the market value of US\$21/AUM¹⁹⁹ by \$2 to allow for the running of cattle in mixed ownership herds with the



Former prairie that has been converted to cropland by sod-busting, Montana.

Grazing rental deductions available for the Matador grass bank arising from implementing conservation actions on a nearby home ranch.	
Conservation action on home ranch	Grazing discount (2008 US\$ values)
Agreement to forego sod-busting (required)	\$0.40 per unploughed but arable acre of private land
Weed prevention, control and monitoring (required)	\$0.50 per AUM
Sustainable range management and monitoring	\$0.10 per acre of private land certified through Undaunted Stewardship
Prairie dog habitat present	\$4–8 per acre of occupied prairie dog town
Sage grouse habitat present	\$0.125 per acre of private land lying within 2 miles of active sage grouse leks
Prescribed fire, riparian or wetland management practices, and other proposals that cost producers grass while leading to conservation	Negotiated
Noxious tree control and prevention	Base rate of \$100 per year for prevention and monitoring; \$10 per tree cut and treated; cap of \$1000 per year

increased risk of exposure to disease, potential for lower pregnancy rates in large herds and reduction in genetic control. Further reduction in rental down to a base value of \$10.50/AUM is then possible depending on the conservation initiatives undertaken on the rancher's own property. Access to grazing on the Matador grass bank is by tender, with applications exceeding grazing capacity. The graziers themselves are part of the management committee that runs Matador and are involved in all the key decisions over ranch management. The Nature Conservancy staff primarily look after the infrastructure and monitor biodiversity values.

Although only running since 2000, the grass bank scheme is already regarded as a tremendous success. As well as protection of key conservation values on Matador, the scheme has resulted in some 100 000 ha of prairie-friendly ranching beyond Matador,²⁰⁰ including 27 000 ha of private land protected from sod-busting, active weed management on 100 000 ha of private, tribal and public leasehold land, certification of 37 000 ha as sustainably managed through the Montana State University 'Undaunted Stewardship Program', and the protection of 1400 ha of prairie dog habitat and 11 000 ha of sage grouse habitat. But perhaps more impressive than these statistics has been the development of a strong ethic of stewardship and biodiversity conservation among the Montana ranchers involved with the Matador grass bank. That the scheme is over-subscribed is testament to the interest and motivation that this grass bank has engendered.

Grass banking has considerable potential in New Zealand, although probably not in the Australian rangelands where cattle grazing does not mimic macropod grazing. However, in areas with more developed agriculture, grass banks could be used to allow farmers to offset production losses associated with conservation work undertaken on their properties through reduced grazing rentals on the grass bank property or for the purchase of forage (e.g. hay or silage) produced on the



Sage grouse are one of the species that benefit from the Matador Ranch grass bank, Montana. (Photo: The Nature Conservancy)



Managing both the spatial and temporal patterns of cattle grazing is essential to maintaining habitat for native plants and animals.

grass bank at reduced rates. Such systems would work best when the grass bank and participating properties are located in close proximity and perhaps form part of a single landcare group with a common conservation goal (e.g. reconnection and restoration of a riparian system).

Private stewardship – Bushland Conservation Pty Ltd

John Smyth has often done things a little differently to others. When he was farming at Salter Springs in the Lower North of South Australia, he was interested in conservation farming and always preferred rotating his cereal paddocks into legumes rather than applying large quantities of nitrogen to his land. His passion for nature came from his dad, who was a keen amateur naturalist. His father set aside an area of 30 ha of peppermint box and SA blue gum on the family farm long before it was fashionable to do so, and John and his brothers would accompany their father on forays into the scrub to study the plants and animals.

It was not surprising, then, that John, with the help of like-minded ordinary citizens, did something extraordinary in nature conservation circles in the mid-1970s, establishing a model of private stewardship that is still unusual today. Artist friend Robert ‘Alf’ Hannaford was living on Kangaroo Island at the time, when a 971-ha

wilderness block of dense mallee came up for sale near False Cape on the south coast of Dudley Peninsula. Both men were concerned about the rapid rate of clearing of native vegetation in SA, prior to the introduction of controls. So with brothers, Ian Hannaford and the late Dr Michael Smyth, they formed a private company in 1975 and purchased the land for \$10 an acre.

Over time, the company grew in size to become Bushland Conservation Pty Ltd, with 73 members owning 49 shareholdings, close to the limit of 50 under Australian corporations law. The company enlarged their Kangaroo Island property to 1379 ha by purchasing contiguous bushland, bought two separate blocks totalling 661 ha in the Tothill Ranges in the Lower North in the early 1990s, and purchased 121 ha of degraded but diverse and threatened woodland, banksia scrub and spinifex grassland near Rockleigh in the eastern Mount Lofty Ranges in 1999.

The business model established by Bushland Conservation Pty Ltd is interesting. The minimum buy-in per shareholding is \$5000, with the value of shares incremented by the consumer price index. John is the honorary company secretary and structures operations to minimise costs and leverage management funds where possible. Since the Valuer-General puts a notional value for rating purposes of \$0 on covenanted heritage land in SA, all company land possible is placed under heritage agreement with the state government so that rates are not levied on company properties.

In the case of the Tothill property, the company did a deal with an owner from whom land was bought by offering them a share in lieu of full payment. This worked because the previous owner was happy to retain a small interest in the land. Arable land included in a purchase was also swapped for scrub to obtain more high-conservation-value land.

In the case of the Rockleigh purchase, the commonwealth government contributed \$60 000 from the National Reserve System budget to match Bushland Conservation’s \$30 000. SA government heritage grants have funded management plans for



John Smyth OAM and his yaccas. (Photo: Margaret Smyth)



View to the east across part of Bushland Conservation's Tothill Ranges property.

each of the properties, which have been drawn up by shareholders with appropriate professional experience. The company is registered as a landcare group, and is able to secure landcare funding and NRM funds through catchment boards.

Originally much of Kangaroo Island land was crown leasehold, but when the SA government offered a generous freeholding scheme, the company converted multiple leasehold sections to freehold for \$3000, avoiding future lease payments. The company still leases a 60-ha narrow strip of coastal frontage, which is not available to freehold. Management of the properties necessarily incurs costs, not all of which can be covered by government grants, and so shareholders are asked to make a \$100 injection every few years to fund management works.

The Kangaroo Island property has few management issues. Some fencing needed to be done early on, and a couple of bushfires have occurred, including one that burnt a third of the property. Fire is to be expected and does not unduly concern the shareholders, although fences have to be rebuilt. John organised the early fencing, but increasingly the state environment department and NRM boards in SA have assisted with heritage fencing grants. John also organises the culling of kangaroos as necessary, and obtains the permits.



Bridal creeper showing the leaf chlorosis and necrosis typical of the rust fungus biocontrol agent, *Puccinia myrsiphylli*. (Photo: Penny Paton)

Weed and pest animal control is ongoing, targeting species that pose most threat to the native bushland in the long term. The Kangaroo Island property has small areas of bridal creeper, now infested with the biocontrol rust fungus and no longer being sprayed, as well as the occasional boxthorn at the coast. The Tothill land has scattered small patches of soursobs, which when found are recorded by GPS and sprayed with metsulfuron methyl using a hand-held garden spray. John walks the 11-km length of the property once each year, relocating each patch for a follow-up spray if needed. This takes less than 2 days but is hard work, as the terrain is steep and rocky. Rabbits occur in the sandy soil at the Rockleigh property and a couple of shareholders have taken on their control. Another local shareholder baits foxes with 1080 on the Tothill land.

Being close to the maximum size of a private company, Bushland Conservation is unlikely to grow further. The amount of voluntary work and funds required of shareholders is close to the amount that could be reasonably expected. The shareholders are aging, and a few shareholders do most of the work. However, the model has caught on, and some members have formed two similar companies to purchase additional conservation properties.



Yam daisies at the Tothill Ranges property. Once common, this perennial herb has declined precipitously across south-eastern Australia due to continuous sheep grazing.

The value of the company's holdings is appreciating strongly, which is a problem, since older shareholders are starting to qualify for the aged pension. The Australian government needs to change its social securities legislation to exempt private land covenanted and managed for conservation from assessable value, in the same way that Aboriginal and public land managed for heritage is exempt.

The biodiversity value of Bushland Conservation's properties is high. The Tothill Ranges is one of the few large remnants of native vegetation anywhere in the Lower North and thus has tremendous heritage value. It is isolated by tens of kilometres of farmland from other large areas of native vegetation, which reduces the number of species likely to survive there in the long term, but increases its regional conservation significance. Flora surveys have recorded more than 250 native plant species.

Until the Tothill purchases, the company had no income stream from its investments. Some 20 ha of land along the lower slopes of the Tothill Ranges property had been ring-barked or was arable but had not been farmed for years. John trialled direct seeding of locally occurring trees and shrubs in these areas in the early 1990s with great success. The regeneration is now up to 5 m high and Bushland Conservation has received payment for



Eighteen-year-old direct seeding at the Tothill Ranges property, which delivers a carbon-credit income stream that is reinvested in on-ground management.

the carbon credits, making a useful contribution to management costs.

One of the successful features of the Bushland Conservation model is positive neighbour relations. A retired farmer like John can easily liaise with the company's rural neighbours and deal with problems as they arise. The only 'heat' felt by members was the initial reaction by the farming community on Kangaroo Island to the notion that farmers would buy virgin scrub only to 'lock it up' and impede the Island's development and progress. Those attitudes are now fortunately in the past.

The Bushland Conservation model of private stewardship should be emulated elsewhere, although legislative amendments by the commonwealth would greatly facilitate uptake. The model involves high conservation value land being conserved and managed by private citizens at a fraction of the cost of the public conservation estate. It is therefore favoured by some in government for obvious reasons.

For their pioneering efforts in nature conservation, Bushland Conservation was awarded the Bushcare Nature Conservation Award nationally in 1998. For his individual contribution to bushland conservation and sustainable farming, John was awarded an Order of Australia Medal in the 2010 Australia Day Honours List.

Environmental certification

There is increasing interest and perhaps some scepticism among farming groups in environmental certification as a means for gaining marketing advantage for their products. Environmental certification is similar to organic certification, with farmers who meet the requirements of a scheme able to market their products using the scheme's logo. As the theory goes, discerning buyers preferentially purchase these products, providing the producer with a better price or better market access than that enjoyed by non-certified producers. Perhaps the best developed international environmental certification systems are in forestry, where certified forest companies are able to access markets, especially in the US and Europe, that are unavailable to non-certified timber producers and wood products, although there is an increasing number of wildlife friendly eco-labels covering a range of products including vegetables, meat, fish, coffee, flowers, fibres and even manufactured goods.²⁰¹

To gain environmental certification, a farmer needs to undertake specified activities in addition to normal farming operations, which are spelled out in the certification scheme standards. Although variation occurs between schemes, these would most likely include:

- Production of an environmental management plan that outlines both the philosophy of the property and the specific on-ground environmental actions that are being undertaken to meet short and long-term management goals
- Implementation of on-ground management activities (e.g. fencing remnants, riparian restoration, removing weed sources, reducing chemical use) as part of routine farm operations
- Undertaking monitoring to track changes in key environmental attributes (e.g. water quality, land cover, bird abundance) and document changes.

Once the farmer feels that they have achieved the standard and have the necessary documentation together, an independent auditor assesses the farm operation against the standard. If the audit is successful, the farm

business is awarded certification. The farmer is then able to market their products using the certifier's logo, but is usually required to undergo regular follow-up audits to ensure that the standards continue to be met, if not improved upon.

Environmental certification systems differ from ISO 14000 series standards in that the latter focus primarily on having environmental management systems in place, while environmental certification systems focus on on-ground environmental outcomes (e.g. water quality or biodiversity condition).

Forest certification schemes arose out of concerns about the unsustainable harvesting of tropical forests, but quickly expanded to focus more broadly on forest sustainability throughout the world, including tenure issues, indigenous people's rights, employment relations, health and safety, and environmental issues. Both forest producers and processing companies can gain certification, allowing a consumer to be sure that both the production and manufacture of a timber product meets the standards. Forest certification schemes have enjoyed considerable uptake globally, with two main schemes (Forest Stewardship Council and Programme for the Endorsement of Forest Certification)²⁰² now certifying some 380 million ha of forest (an area just under half the size of Australia). The power of these certification systems in the developed world is such that a major retail chain like Home Depot in the US can source all its timber products from certified forests, while 50% of all timber imported into the UK in 2008 was certified.



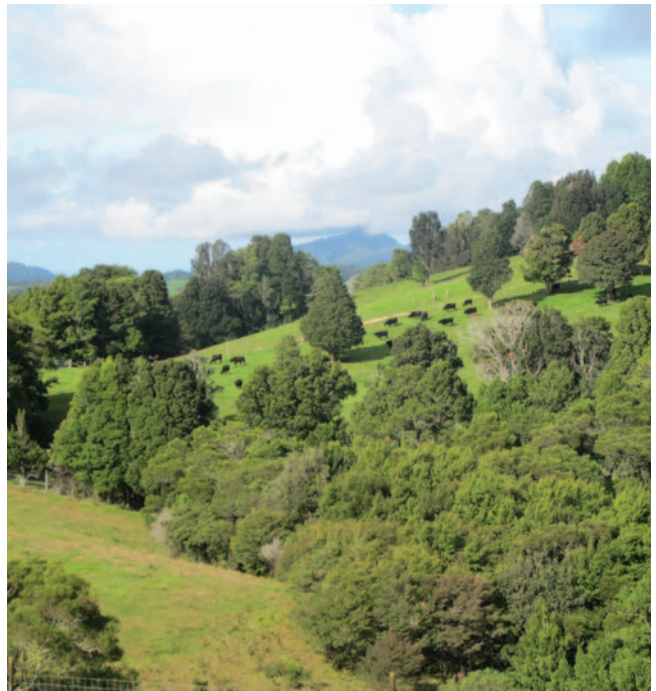
The agricultural sector has been slower to take up environmental certification systems than forestry, although there is increasing market pressure for this to occur. Many producer companies now require their suppliers to meet certain environmental standards. For example, multinational dairy company, Fonterra, has developed a ‘clean-streams’ accord with the New Zealand government that seeks among other things to have dairy cattle excluded from 90% of streams, rivers and lakes by 2012, which is particularly significant as dairy farming accounts for >10% of the New Zealand agricultural land area.²⁰³ Individual producers have also sought to market their products based around minimising environmental impacts. The ‘wax-tip’ eco banana label from Queensland is a good example.²⁰⁴ Developed by Frank and Dianne Sciacca, the system focuses on the sustainable production of quality bananas while minimising environmental impacts through reduced agrichemical use, enhanced soil health and more efficient water use, thus improving both on-farm ecosystem condition and reducing downstream impacts (e.g. on the Great Barrier Reef).

Broader environmental certification schemes similar to those being used in forestry are still limited in the agricultural sector, although in the United Kingdom,

the LEAF (Linking Environment and Farming) Marque²⁰⁵ standard is gaining increasing traction with consumers and supermarket chains such as Waitrose with 183 stores across the UK now stocking products certified by LEAF Marque. LEAF was set up in 1991 by a group of farmers, environmentalists, food and agricultural organisations, consumers, government and academics to develop a farming system that would help farmers improve both their farm environment and their business in an economically viable and environmentally responsible manner. The core element of LEAF is integrated farm management (IFM), which aims to integrate beneficial natural processes into modern farming practices using advanced technology such as GPS to ensure the highest standards of food production with the minimum environmental impact. LEAF advocates IFM principles through a nation-wide network of demonstration farms showing other farmers how to adopt IFM. LEAF Marque-certified products include meat, dairy products, cereals, potatoes, vegetables, flowers and wine. LEAF is also part of a European-wide movement – the European Initiative for Sustainable Agriculture, which has similar projects in Germany, France, Italy, Sweden and Luxembourg.



Forest Stewardship Council-certified Double Crossing radiata pine plantation forest, Hawke's Bay, with high-conservation-value native forest in foreground (Photo: Kit Richards)



Many farms are well suited for environmental certification because of high levels of biodiversity, conservative management and an ethic that is compatible with the principles of sustainable land management.



LEAF-certified spinach ready for the supermarket. (Photo: Linking Environment and Farming)

Consumer demand drives certification rather than regulatory requirements. In a world where people have more disposable income than ever and where environmental issues are increasingly in the spotlight, discerning customers are seeking products that satisfy their desire for environmental responsibility. The influence of the consumer is perhaps nowhere more clear than in the debate over mulesing. As a result, the New Zealand Merino Company has brought in its own certification scheme called Zque²⁰⁶ that, as well as including a no-mulesing requirement for farmer suppliers, also covers environmental and traceability issues. Clothing manufacturers such as Icebreaker in New Zealand, John Smedley in the UK and SmartWool in the US use only Merino fibre with Zque certification in their garments. Each Icebreaker garment also includes a 'Baacode' which enables the purchaser to identify the properties that the wool was sourced from and information about the property and the farming family.²⁰⁷ Japanese consumers are increasingly using similar technology to trace the origin of food products such as the beef they are purchasing in the supermarket while making their purchases; barcodes on products



Icebreaker garment 'Baacode' and website (<www.icebreaker.com>) with information on one of the properties the wool in the garment was sourced from.

can be scanned in the shop using a smart phone to provide information on the source of the product and the way it was managed.

The farming sector has been slow to take up environmental certification. But in a world where consumer preferences increasingly dictate retail product choice, participation in certification schemes may be critical for differentiating products and ensuring market access. This is especially so for producers in Australia and New Zealand, who face pressure over 'food miles' and need to be proactive in highlighting why their products are environmentally better than comparable products from the countries they are marketing to. The predominance of 'free-range' farming and the ability to integrate farm production with biodiversity conservation and other environmental considerations will be important for achieving this. Experience from forestry suggests that price advantages associated with certified products are less important than market access, but it is access to the high-value markets in Europe, North America and Japan that will provide the greatest returns for Australian and New Zealand producers.

Landcare

Landcare provides the quintessential contrast to top-down intervention by governments and their bureaucracies for achieving conservation of natural resources and enhancing natural capital. Australia has a national landcare network of more than 4000 locally based community groups comprised entirely of volunteers looking after country.²⁰⁸ More than 40% of Australian farmers are involved in landcare, for whom it has been an important source of support and capacity building in natural resource management (NRM) as well as for growing and sustaining social and community networks.

The strength of landcare is its local focus and character and the fact that community groups and networks decide their own visions and set goals for environmental action in their districts and regions. Groups are supported by government and the private sector in implementing plans

to tackle land and water degradation and implement sustainable NRM.²⁰⁹ Working from the ground up to achieve these goals creates freedom and flexibility, giving communities a greater sense of purpose. The range of environmental activities of landcare groups is broad and includes combating soil salinity and erosion, conserving and rehabilitating rivers and streams, planting native trees, shrubs and grasses for a range of benefits, regenerating bushland and wildlife habitat, and conserving areas of environmental significance on both private and public land.

The landcare model was developed in Australia²¹⁰ but other countries including New Zealand have introduced and developed their own variants.²¹¹ Landcare groups operate essentially autonomously, but use the technical, administrative or financial assistance of government and



Landcare brings volunteers together for a wide range of land and water management activities and community services. (Photo: Ellen Nyberg)



A group learning about ponding banks for holding up runoff and encouraging infiltration in surface sealing soils in western NSW rangeland. Landcare groups are an efficient way for agencies to extend technical information.



An urban landcare group funded by Caring for our Country, planting native tree and shrub seedlings in the riparian zone of Dumaresq Creek, Armidale, NSW. (Photo: Ellen Nyberg)

the private sector to tackle resource degradation, and plan and adopt more sustainable resource use practices at the local level.²¹² The collective action of landcare groups can take many forms, including meetings, field days, on-ground works, and farm and regional planning. Landcare groups provide a means of disseminating extension advice and financial assistance for projects directed at treating and preventing resource degradation problems, and promoting public-good conservation measures.

Landcare was introduced to tackle biophysical issues in NRM in the 1980s. However, its social function of educating and empowering individuals and local groups to make more sustainable use of the land has been equally important,²¹³ with the goal of both protecting the natural resource base and sustaining profitable farm businesses.²¹⁴ The best outcomes have been achieved where local commitment and capacity for change has been matched by government with knowledge, resources and institutional willingness to adapt to new models of sustainable land use.

Landcare has a number of benefits and implications for policy and decision makers:²¹⁵

1. Land degradation and natural resource and farm sustainability issues do not necessarily follow farm boundaries (e.g. salinity, rural tree decline, pests and weeds, disease, biodiversity conservation, river health, etc.). A district, regional or catchment approach to these problems is essential.
2. When extension funds and staff time are limited, farmers are more likely to receive NRM advice in groups rather than as individuals. Groups are usually more demanding, better at lobbying and place more pressure on officers for advice or assistance.
3. Groups can pool ideas, resources and labour. Individuals benefit from the diversity of skills and experience in the group.
4. Groups are sustained by a complex mix of peer pressure, leadership, mutual coercion, encouragement and support from external agencies. The mixture encourages many hours of voluntary time and labour.

5. Groups provide a focus for non-farming residents in a district to interact with them in a constructive way.
6. Groups provide extension agents with a wider variety of farmers than they would otherwise meet, including influential opinion leaders and reticent farmers who would be unlikely to seek assistance on their own.

Landcare encourages communities to recognise and 'own' their own problems and, with the help of agency and research staff, to devise appropriate local solutions largely financed by the groups themselves. Although the funds provided by government through various programs have been critical in catalysing group formation and development, private investment of two to six times the government funds has been leveraged from landcare group members as a result.²¹⁶ Landcare is thus an efficient use of government resources.

As landcare groups have evolved, they have taken on a variety of social functions:²¹⁷

1. **Networking agents:** originally landcare groups started off as discrete entities, but as they matured, completed projects and sought answers to new problems, they developed communication networks

to link groups across regions and the whole country. Regional landcare umbrella networks were established and have persisted, despite sometimes strained relations with catchment management authorities.

2. **Local resource mobilisers:** having identified and confronted their problems, landcare groups look for solutions. In doing so, they mobilise local resources including land, labour, capital, enterprise and local skills, to solve their problems.
3. **Natural resource managers:** in some cases, government has handed back NRM functions to landholders. Kangaroo Creek Landcare Group on the North Coast of NSW is an example where government had handed back responsibility for irrigation water regulation. Government used to manage irrigation water allocation but did a poor job. The landcare group was judged to have the skills to do the job better. Some state agencies have devolved responsibility for the management of crown land back to landcare groups where there is evidence that the groups will manage the land better than government.



A volunteer bushcare group controlling wilding olives on public land in the Mount Lofty Ranges, SA. (Photo: Penny Paton)



The red-browed finch (left) and superb fairy-wren (right) were beneficiaries of the shrub layer in Holbrook Landcare Group's on-farm plantings. (Photos: Lynn Pedler)

The most significant achievements of landcare have been raising awareness of land degradation and sustainability issues, building skills in both practice and decision-making processes, and adopting improved NRM practices on-farm.²¹⁸

Although biodiversity conservation has often not been the main focus of rural landcare group activities, many groups have assisted biodiversity conservation through rural revegetation and some groups and individuals have set out to protect bushland remnants and target endangered species and their habitat. Holbrook Landcare Group in southern NSW initiated a tree planting program in their district after commissioning a tree health survey of their catchment in 1990.²¹⁹ They discovered that half of their large paddock trees were dying from insect attack, less than 20% of the original tree cover remained, and that on the lower slopes, the figure was closer to 1%. When research suggested that birds remove 50–70% of the insects in tree canopies, the group initiated a revegetation project to entice birds back on to farms and reduce eucalypt dieback. Over \$2 million was spent on replanting 2000 ha of the catchment, including 800 ha of native trees and shrubs.

Between 2004 and 2006, CSIRO Sustainable Ecosystems assessed the value of 12 young planted sites (2–3 years old) planted by Holbrook Landcare Group

and compared them with adjacent paddock (scattered tree) sites and remnant woodland sites. Birds were captured and banded to establish their residency and mobility patterns. Of 69 woodland bird species, 70% occurred in planted sites, emphasising the value of the revegetation, compared to 86% in remnant woodland and 49% in paddocks. The increased diversity of birds in planted sites was mainly attributable to understorey species such as superb fairy-wren and red-browed finch. Under-represented in plantings were ground-feeding insectivores, possibly as a result of the lack of native groundlayer vegetation of herbs and low shrubs. The proportion of mist-netted birds recaptured was similar in both planted (15%) and remnant woodland (16%). Fairy-wrens and finches were more frequently recaptured in planted sites than woodland, highlighting the importance of dense shrubbery in the plantings. Slightly more species caught in plantings (69%) had brood patches indicative of breeding than in woodlands (63%).

Holbrook Landcare Group's commitment to revegetation for bird habitat and restoring ecological balance to farmland demonstrates the value of planted sites as transitional habitats for a wide range of native woodland birds, and the importance of dense shrubby understoreys.



Banks Peninsula Conservation Trust

One of the challenges for achieving successful biodiversity conservation in rural areas lies in being able to provide support for farmers implementing biodiversity measures. Such support might include extension work (field days, workshops, etc.), assistance in obtaining funding (e.g. for fencing), help with on-ground work such as weed control, or simply through interacting with a group of like-minded people facing similar challenges. Government agencies can provide some of this support, but voluntary organisations such as landcare groups are often better positioned to do this. The Banks Peninsula Conservation Trust,²²⁰ a not-for-profit organisation, was formed in 2001 to work with landowners and agencies to promote conservation of native biodiversity and sustainable land management on Banks Peninsula, New Zealand.

Banks Peninsula is a 100 000-ha eroded volcanic system jutting out into the Pacific Ocean on the eastern edge of the South Island's Canterbury Plains.²²¹ The peninsula was fully forested when humans first arrived some 700 years ago, but Maori burning and more extensive European burning and felling from the 1830s resulted in almost total replacement of forest with pasture by the early 20th century, with only 800 ha of

old-growth forest remaining. However, the distribution of these small forest remnants across the peninsula, coupled with a benign climate (abundant rainfall and warm temperatures), has resulted in regeneration of native woody vegetation on sites where grazing pressure is low. Removal of government subsidies for clearing regenerating woody vegetation in the early 1980s led to a rapid increase in woody cover. Some 9100 ha of second-growth forest and 4400 ha of native and exotic scrub are now present, which left undisturbed will eventually regenerate into tall native forest.

The Banks Peninsula Conservation Trust developed as a community response to a local government planning process in the late 1990s, which had initially proposed restricting farm development activities over large 'significant natural areas' across the Peninsula. One of the Trust's driving philosophies is the concept that given the right encouragement and resources, a community can and will put in place protection measures to ensure the conservation of native biodiversity without the need for coercion or regulation. The Trust is run by local people, both farmers and non-farmers, with a small part-time staff, although the bulk of the work is undertaken by volunteers. The Trust is totally funded through donations and grants



One of the few remnants of old-growth podocarp–broadleaved forest remaining on Banks Peninsula – here dominated by lowland totara, matai and kahikatea.



A tui feeding on the nectar of harakeke (New Zealand flax). The Banks Peninsula Conservation Trust has been actively involved in the reintroduction of this iconic forest bird.



Banks Peninsula landscape with bush remnants (left), pasture, woodlots and bays.

from a range of organisations including companies, government agencies, charitable trusts and individuals, with an annual operating budget of around \$200 000.

The Banks Peninsula Conservation Trust is involved in a wide range of conservation initiatives including workshops and guided walks, conservation covenants, and restoration, pest management and species re-introduction projects. The Trust had by early 2012 registered 45 covenants protecting 420 ha. Workshops and guided walks have been a key tool to better inform locals about biodiversity values and management approaches, covering a wide range of topics including threatened species, pest management, riparian zone restoration and tussock grassland management.

Two key projects of the Trust have been the eradication of wild goats and the reintroduction of the tui, an endemic New Zealand honeyeater. Wild goats cause havoc to native habitats, especially forests, by ring-barking trees, browsing seedlings and opening up gaps for weed invasion. Some 4000 goats have been shot by the Trust and three government agencies to almost rid Banks Peninsula of this pest. Eliminating the last feral goat is now in sight, but new challenges are emerging with feral deer and pigs.

The Trust has taken a lead role in a program that aims to re-establish tui on Banks Peninsula. This distinctive songbird had almost completely disappeared by the late 1980s largely as a result of predation, but the translocation of birds from predator-free Maud Island in 2009 and 2010 into Hinewai Reserve, a 1230-ha restoration project with intensive mammalian pest control, appears to have been successful with birds now being reported from a range of sites on the Peninsula and successfully fledging young birds. Part of the success of the tui reintroduction program has been the increase in predator control (stoats, ferrets, rats, feral cats and possums) being undertaken by a wide range of people as a result of the Trust's work, creating opportunities for tui to establish and breed.

The great advantage of trusts like the Banks Peninsula Conservation Trust is that they have a critical mass that enables them to access funding that may not be readily available to individual landowners, for example for fencing and weed and animal pest control. Also through their success, and especially through the actions of the individual farmers who form trusts such as this, they work as powerful advocates for biodiversity conservation more generally among rural communities.

QEII National Trust covenants

One of the challenges for managing native biodiversity on private land is ensuring that the conservation gains achieved by the current owner are sustained in the future when the property is owned by others. A common criticism by government agencies and advocacy groups of conservation initiatives undertaken by private individual and companies is that there is no certainty over future management.²²² One way to address this lack of certainty is through the use of covenants that are placed on a property title and bind that title in perpetuity. For example, a covenant on a forest remnant would legally protect the remnant from being cleared now and in the future. In New Zealand, the QEII National Trust is the main organisation helping landowners protect significant natural features on their properties through the use of open space covenants.²²³

The National Trust was established in 1977 through its own Act of Parliament and at 31 January 2012 had 4053 registered or approved covenants covering 119 298 ha of private land, mostly farmland. Covenants range in size from <1 ha to 6564 ha, with an average size of 28.6 ha. The uptake of covenants has been increasing exponentially, with 19 years from the establishment of the National Trust to the registering of the 1000th covenant, 8 years to the 2000th covenant and only 4 more years to the 3000th covenant. But more importantly, a significant proportion of covenants is located in lowland areas of New Zealand where relatively little of the pre-human vegetation remains and where most of this vegetation does not enjoy any form of protection.

In implementing a covenant on a property, the National Trust covers the costs of surveying and registering the covenant on the title, and may assist with some of the fencing costs. The local National Trust representative works with the landowner in developing a management plan for the covenant, and then undertakes regular visits to the covenant to monitor covenant condition and talk to the landowner about any issues that have arisen. In most parts of New Zealand, covenanted land receives rate rebates from local government.

Typical of many QEII covenants is John and Heather Taylor's 18-ha covenant protecting four remnants of lowland podocarp forest on their 235-ha Waikato dairy farm. Livestock were excluded with new fencing, and regeneration is now occurring rapidly. These remnants with a diverse canopy of podocarp and angiosperm trees such as rimu, totara, tawa, titoki and rewarewa are an important stepping stone for forest and birds such as kereru, tui and bellbird moving between the private forest remnants in the area and the nearby Maungakawa Reserve.

The growing popularity of covenants reflects a growing interest among rural landowners in protecting key conservation values on their properties. Some



Distribution of registered QEII open space covenants, November 2010.



A 995-ha QEII open space covenant protecting an internationally significant moraine and tarn system on a New Zealand high country farm, Mackenzie Basin.



Lowland podocarp forest protected in a QEII National Trust covenant on Mangarara Station, Hawke's Bay. (Photo: Greg Hart)

landowners, suspicious of government involvement in biodiversity conservation on private land, see covenants as an appealing alternative, especially because the owner retains title to the land and no coercion is involved in implementing the covenant – their establishment is voluntary. Conservation covenants have been called the ‘single best tool available to preserve family lands and open space’.²²⁴ Furthermore, covenants do not necessarily restrict economic use of the land, with some grassland covenants subject to ongoing monitored grazing (which can be essential for maintaining biodiversity values), while some forest covenants are used for sustainable timber production. The terms of the covenant, and the conditions imposed on the land, are negotiated between the landowner and the National Trust when the covenant is drafted.

While there has been questioning of the reality of the perpetual nature of covenants, the QEII open space covenants have been shown to be binding in perpetuity under New Zealand law.²²⁵ Furthermore adherence to covenant conditions among both original covenantors and subsequent landowners is very good. Results from monitoring 1542 covenants by National Trust staff in 2008–09 found that only 4% were deemed ‘poor’ in terms of adherence to covenant conditions, with these split evenly between originating covenantors

and subsequent owners. In cases of poor adherence, National Trust staff work with the owner to address the issues.

Covenants are also widely used in Australia under the Heritage Agreements Scheme run by various state governments. For example, in South Australia nearly 1500 Heritage Agreements covering some 620 000 ha have been signed between the state government and private landowners.²²⁶ As with QEII covenants, Heritage Agreements run in perpetuity with the title of the property. In SA, areas subject to Heritage Agreements enjoy rates relief and the government helps with fencing costs as well as providing funds for on-ground management work.

A real strength of covenants and heritage agreements is that the lands remain in private ownership, managed by the owner rather than by an external agency. Covenants can help foster landowners’ sense of stewardship.²²⁷ Moreover, most threats to indigenous biodiversity in the small remnants commonly protected by covenants arise from the remnant’s location within a predominantly rural matrix. The landowner is in the best position to manage the surrounding landscape in a manner that benefits the covenant as well, and the New Zealand experience suggests that almost all covenant holders do this well.

Brian Molloy – a New Zealand scientist making a difference

One of the challenges of implementing biodiversity conservation on farms is ensuring that farmers have the knowledge to be able to appreciate the biodiversity values that are present on their property, why these values are important, and what farm managers can do to ensure their sustainability. As Frances Bacon wrote in 1597, ‘for also knowledge itself is power’. Unfortunately in modern rural conservation debates, biodiversity knowledge is held by a select few (e.g. scientists and government agency staff) and often used as a means to secure particular outcomes that farmers have little ability to counter, thus engendering much ill-feeling towards conservation.

Farmers are, of course, busy people who run large and often complex businesses, having little time to familiarise themselves with the intricacies of an area’s natural history beyond that necessary for farm management. However, farmers are also astute observers of nature as the viability

of their farming operation is usually highly dependent on a good knowledge of landforms and soils, plant and animal productivity, and climate. However, once farmers have access to biodiversity knowledge, they are able to engage in conservation debates and implement conservation actions on their own without the need for regulatory pressure. The key, then, is for effective knowledge transfer.

Knowledge transfer can occur in many ways. In some instances, government agencies, NGOs and other organisations provide information through field days, presentations at farmer meetings or through various publications. Landcare groups have been successful avenues for knowledge dissemination in both Australia and New Zealand. Another means of transferring knowledge has involved scientists taking the time to work with rural communities to ensure that they have this information, although few scientists have been



Brian Molloy (centre) talking to a group of Banks Peninsula farmers on a tussock grassland field day.



Sophora molloyi, a bushy shrub of coastal environments named in honour of Brian Molloy. (Photo: Jeremy Rolfe)

successful at this. One such scientist is Brian Molloy, a now retired botanist and ecologist, who worked for Botany Division, DSIR, and Landcare Research, two New Zealand government-funded research institutions.

Brian completed diplomas in agriculture and teaching, and then a Masters and doctorate in ecology while working for the Department of Agriculture in the late 1950s. His initial research was on landscape history and weed ecology, but he quickly developed an interest in conservation. However, unlike many of his contemporaries, his research focused on biodiversity in agricultural landscapes rather than national parks and other remote natural areas. As well as being the first scientist to recognise the profound impact of Polynesian settlement on New Zealand vegetation, Brian published a number of key papers on biodiversity conservation in agricultural systems including a 1971 paper titled 'Possibilities and problems for nature conservation in a closely settled area.'²²⁸ However, it has been his 'on-the-ground' involvement with farmers that has been critical for biodiversity knowledge transfer.

As a result of spending his early days working on farms, Brian quickly realised the importance of viable farming operations for biodiversity conservation: 'you don't get far in the green world if you are in the red'. He argues that 'Trying to take land away from farmers is not the answer. Rather, you have to work with farmers to help them integrate biodiversity management into their overall farming operations.' He strongly believes that the



Brian Molloy looking at plants of an undescribed species of spaniard.

key to successfully sharing biodiversity knowledge with farmers is to listen to what farmers have to say and to talk 'with' them, not 'to' them. He argues that time spent talking around the kitchen table or looking at a wetland at the back of the farm results in much bigger gains for conservation than publications in scientific journals. Brian comments that scientists need to be clear about who they are doing research for: 'Modern scientists are too fixated with publications, but it is the land managers who should be benefiting from our work. To do that, it is essential that we talk with them.'

Brian's contribution to science was recently recognised through his election as a Companion of the Royal Society of New Zealand. This award recognises both his outstanding leadership in botany and ecology, and his willingness to share his knowledge.

As well as his work as a government scientist, Brian also spent nine years as a member of the QEII National Trust Board, the statutory limit for board membership, and more recently has been the QEII field representative for the South Island high country. Through this he has spent much time working with farmers whose properties have important biodiversity values, helping them establish covenants for the perpetual protection



Sixteen Mile Creek QEII open space covenant, one of four on The Branches, a high country station in the Otago Lakes District. Brian has spent many years working with farmers in establishing covenants such as this.

of these values. Brian believes that his background in agriculture and earth sciences (geology and soils), as well as in botany and ecology, is critical for being able to properly appreciate the significance of a site and implement appropriate conservation management in order to sustain the values present. He also commented that his early teacher training helped him learn how to communicate with people.

Brian suggests that when visiting a new site, the key questions that need to be considered are, 'Where the site has come from? What is it like now? And where is it going?' Discussing these with the farmer is critical for implementing appropriate conservation management. Brian also notes that 'It is one thing to protect and another thing altogether to manage.'

Brian has also been very active as a Trustee, appointed by the Royal Society of New Zealand, of the Riccarton Bush Trust. Riccarton Bush or Putaringamotu is a unique 7-ha remnant of lowland kahikatea forest now within the boundaries of the city of Christchurch.

It is arguably the oldest protected natural area in New Zealand; its protection effectively dates from the death-bed wish of John Deans in 1854. Brian has been involved with Riccarton Bush since the early 1970s and has played a key role in guiding its restoration from a degraded parkland-like forest remnant to the vibrant stand of healthy native forest it is today. Again, as with all of Brian's work, the key to this process has been to work closely with the different individuals and groups who have an active interest and involvement in the bush. He has always been a strong advocate of the area's educational and conservation values.

Brian has a take-home message for successfully working with farmers. 'It is essential to take time, listen to what they have to say, take them out and show them the values on the ground, and provide feedback on what you have seen and discussed.' Having been a member of the All Black team that toured Australia in 1957 has certainly helped Brian develop relationships with farmers, especially those from that generation!

David Curtis – an Australian scientist making a difference

David Curtis has worked as a farm labourer, technician, university tutor, lecturer, research ecologist, extension agent, regional manager of a national non-governmental organisation, social scientist, catchment officer and senior policy analyst in his 35-year career. David is also a musician, singer-songwriter, actor, playwright, artistic producer and director, integrating the arts in his professional and community activities. David's concerns about the environment and the ecological profligacy of modern society have driven his scientific, artistic and community endeavours, which in turn have affected the work, environment and lives of thousands of people on farms, in country towns, regional centres and cities in Australia and elsewhere. This case study profiles the life and work of this modest individual who insists that he hasn't really done that much 'except play double bass in a band'.

David was born in Wangaratta, Victoria, in 1955. His parents, Helen and Peter, and grandfather, Sidney Newman, were important influences, particularly his mother's passion for botany, working with his father on the family farm, and on visits with his grandfather, who was an engineer. Sid was responsible for the construction of many of the major tram interchanges in Melbourne, but he was also interested in organic farming, municipal composting, bushwalking and conservation long before such passions became fashionable.

David's final year at Wangaratta High School was a watershed in his lifetime of inquiry and environmentalism. His science and English teachers encouraged his peer group to investigate a wide range of environmental issues inside and outside of the classroom, including energy, garbage, pollution, native plants, composting, solar hot water, farm forestry and soil erosion. He progressed to biological science at the University of New England (UNE, 1973–75) and after a year travelling overseas, worked as a botanist at the University of Sydney (1977–81). In Sydney, David met a group of like-minded environmentalists and actors in the New Theatre street theatre group, including his future wife, Fran, and formed the Streuth Troupe. For

3 years, they performed street theatre about energy and consumerism in malls, beaches, parks, festivals, rallies, outside the Opera House, in public spaces around Sydney and in regional towns. This time was important for developing values and honing the performance skills of a lifetime.

With Fran and their first-born child, Ellen, David returned to UNE in 1982 to take up a tutorship in botany and undertake research into eucalypt regeneration for his MSc. The research involved revegetation and monitoring of over 15 000 planted seedlings, 6 ha of direct seeding and 150 ha of natural regeneration. Amidst all of this and the arrival of Ellen's two brothers, Huon and Robin, David gained formal qualifications in adult education (DipEd, 1987) and founded the Armidale Tree Group (ATG) with fellow dieback researcher, Chris Nadolny. ATG has since grown into a nursery, contract planting business and woodland education centre employing several staff and propagating and establishing over a million native trees and shrubs in the region. David



David planting native tree seedlings in 1986 on the foreshore at Malpas Dam, NSW. The plantings were designed to be a riparian buffer to improve water quality and were the first major planting of native trees on the Northern Tablelands of NSW following the worst years of New England dieback in the late 1970s and early 1980s. (Photo courtesy of Tony Grant)

coordinated ATG until 1990, is a life member, and continues to be involved with the group.

In 1990, Greening Australia was contracted to administer the federal government's One Billion Tree Program to conserve and establish trees and native vegetation throughout the country. David was appointed Manager of the north-west regional office of Greening Australia NSW. His activities were initially focused on extension and community development and facilitation. However, with funding from the federal government's Landcare Environment Action Program, David soon expanded Greening Australia Northwest's business to a point where he employed more than 30 staff with a payroll of 180 working out of ten district depots. The Dorrigo operation was so successful under the direction of the late Mark Sandstrom that it evolved into a new regional office of Greening Australia, servicing the mid North Coast of NSW and the Dorrigo Plateau.

The labour market programs ended in the mid-1990s but funding from the Natural Heritage Trust allowed

David's team of 10 to diversify into farm forestry and bushland conservation, farm planning and revegetation, and numerous small contracts and projects.

In the 10 years to 2000 with David at the helm, Greening Australia Northwest planted 1.3 million native trees and shrubs, established some of the first farm forestry plantings using native species on private land in the region, and protected about 8000 ha of bush. The team published over 100 articles, books, posters, kits, brochures and newsletters, wrote more than 100 newspaper columns for regional media, and serviced over 2600 clients and organisations. The regional team co-sponsored and co-supervised university students (masters, graduate diplomas and bachelor student projects) in research on plains dieback and other ecological and tree management topics. Giants among the regional farming community's many avid tree planters, such as Michelle and John Lynn at 'Blairmore' and Vicki and Jon Taylor at 'The Hill' (p. 209), acknowledge David's important catalytic role in assisting their initial efforts



The late Mark Sandstrom explaining 'J'-rooting in a plantation eucalypt to students on a farm at Dorrigo, NSW.



David (left) leading a workshop at a *Vegetation Futures* conference on the use of the visual and performing arts in communicating science and changing environmental behaviour. (Photo courtesy of David Curtis)

to plant native vegetation. Many of the people employed by David in the 1990s have since gone on to make major contributions to agriculture and the environment.

David's main preoccupation throughout his time at Greening Australia was engaging farmers about native vegetation and ecology. He had to distil sometimes complex science and agronomy into key messages, as well as learn alongside producers how to plant and protect native vegetation on farms for production, conservation or both. Given his artistic talents, David incorporated both the performing and visual arts in his extension work in the paddock, farmer workshops, conferences, and talks to community and student groups. His aim was to create 'memorable moments' to help his audiences recall important information and encourage on-ground work.

Given the convergence of David's artistic creativity and passion for environmental extension, David found time after being appointed National Program Manager of Greening Australia's 'Bush for Greenhouse' program in 2000 to write two successful grant applications. With funds from Land & Water Australia and the Rural Industries Research & Development Corporation,

he undertook a doctorate at UNE between 2002 and 2007 on the role of the visual and performing arts in influencing environmental behaviour. His research involved interviewing more than 100 artists, farmers and extension agents about the nexus between art and environmental attitudes and behaviour. He found that the visual and performing arts influence people's environmental values, attitudes and behaviour in three ways: by communicating environmental information, creating empathy for the natural environment, and catalysing environmental sustainability.

In recent years, David has worked as a catchment officer to promote native vegetation protection on farms, and with the NSW government as a principal policy officer reviewing native vegetation regulations. He currently works for the NSW Department of Primary Industries advising on native vegetation policy and assisting the state's catchment management authorities to develop catchment action plans.

David continues to be inspired by the potential for the arts to transform society for environmental good. He commissioned Ralph Steadman to script *God's Drawing Board*, an ecological oratorio for the Armidale



David and friends formed the eco-band *Tre Los Lantana* in 1997 to play gigs and write songs popularising contemporary environmental issues. From back left, clockwise, Gary Jenkins, Mark Cooper (disguised), Louise Drielsma, David Curtis, Lynn Everett, David Carr, Fran Curtis and Camille Dunsford (with David's children Robin and Ellen in disguise). Not pictured, Michael Drielsma. (Photo courtesy of David Curtis)

community with music by composer, Elena Kats-Chernin. The work premiered in 2008, in collaboration with Bruce Menzies, and tells the story of dieback and regeneration in New England. It celebrates the lives and work of two of David's late friends, Mike O'Keeffe and Mark Sandstrom, who loom large in the region's native tree planting movement.

Reflecting on his career, David attributes his many successes and achievements to two critical ingredients: 'first, strong collaborations with long-time associates, many of whom have become close friends – Dave Carr, Kerry Steller, Garry Slocombe, Bruce Menzies, Chris

Nadolny, Ian Reeve, Andrew Parker, and the late Mike O'Keeffe and Mark Sandstrom, among many others. It is close working relationships with others that I find so important. Secondly, while a scientific rationalist view of the world has formed the bedrock of my thinking and work, I have always tried to combine science with other disciplines – whether it be environmental education, community development, extension, or the arts and humanities.' David's approach offers a way forward for all of us in the troubled 21st century: working together for an environmentally sustainable, culturally enriched future.

9

APPROACHES TO MANAGING BIODIVERSITY ON THE GROUND

In this chapter we consider a range of examples of on-ground biodiversity management approaches in agricultural systems. The individual case studies cover a range of different types of agricultural systems (including horticulture and forestry) and represent real-life examples of what primary producers are doing today to manage biodiversity as part of routine farm operations. Although weed and pest control and revegetation methods for propagating and establishing native plants

are mentioned in passing, they are not focused on or detailed here, as they are well covered in other places.²²⁹

Some of the case studies are quite specific to particular places, farms or ecosystem types, while others are more generic and could be applied across a range of different farms or ecosystem types. The intent of this section is not to provide readers with a 'cookbook' of methods and techniques that could be used, but rather to provide an overview of the diversity of approaches being taken.



Volunteers assisting with restoration plantings. (Photo: Ellen Nyberg)

Remnant management in New Zealand

As New Zealand's forests evolved in the absence of grazing mammals, the first priority for remnant management is usually the removal and exclusion of grazing animals.²³⁰ There is a substantial body of ecological literature that highlights the adverse effects of domestic and wild grazing animals on forest composition.²³¹ In particular, grazing animals deplete the understorey vegetation, prevent regeneration of many canopy trees, alter soil conditions (e.g. through compaction and nutrient input) and spread weed species. Domestic stock can be readily fenced out, but other approaches are required for feral animals such as deer and goats. There is evidence to suggest that even at low densities, feral animals such as deer suppress palatable plant species in severely degraded forests.²³² Their control requires the erection of more substantive fences (e.g. deer fences), or a commitment to ongoing control (e.g. by shooting) both in the remnant and in adjacent areas.

The other major factor affecting remnant vegetation is browsing by brushtail possums. Brushtail possums were introduced to New Zealand from Australia to establish a fur trade, but in the absence of natural enemies they spread rapidly and today threaten both biodiversity and economic values. Possum control is widespread across rural New Zealand, mainly because possums are a vector

for bovine tuberculosis. This control has important benefits for remnant management as it helps keep possum numbers low. However, many farmers who manage remnants undertake additional possum control, usually based on a mixture of shooting, kill-traps and poison bait stations, to further reduce biodiversity impacts. At their worst, possums have resulted in substantial changes in forest composition with some tree species becoming locally extinct in areas with heavy and prolonged possum infestations,²³³ so possum control is a good way to help sustain native biodiversity.

New Zealand's fauna, dominated by birds, lizards and unusually large invertebrates, has been ravaged by introduced predators, especially rodents and mustelids (stoats and ferrets).²³⁴ While habitat loss has also had a major impact on some bird species, predation appears to be the single biggest factor limiting forest birds both in remnants and in the large areas of public conservation land.²³⁵ Numerous studies have shown the benefits of predator control for bird populations, and increasingly farmers are also implementing predator control as part of their remnant management. Predator control in small remnants is reasonably straight forward involving a mixture of kill-traps and bait stations, but as many birds have large home ranges



Forest understorey regeneration between 2006 (left) and 2009 (right) as a result of the removal of cattle and sheep, North Canterbury.



Heavily grazed lowland conifer forest remnant, New Zealand.

(e.g. tui [honeyeater] and kereru [pigeon]), control beyond the remnant boundary is usually required to ensure recovery. For some birds, especially penguins nesting in coastal forest and shrubland remnants, predator control around nesting sites is essential to ensure their survival. Recent research by Raphael Didham, now at the University of Western Australia, and his co-workers has shown that mammalian pest control in the absence of domestic stock removal is not as effective at restoring native forest floor invertebrates in New Zealand kahikatea forest remnants as when both are undertaken together.²³⁶

There has been increasing interest in the use of predator-proof fences to exclude all invasive mammals from forest remnants. Absolute exclusion is always better than ongoing pest management, but it does have a large up-front cost in that predator-proof fences are significantly more expensive than conventional fences and, as with any fence, require ongoing management.²³⁷ One breach of the fence, for example due to tree fall or stream erosion, will allow pest species to re-enter. Predator-proof fences also do not exclude exotic birds, invertebrates or plants.



Predator-proof fences are one approach to managing invasive mammals. This one is at Australian Wildlife Conservancy's Yookamurra Sanctuary in the Murray Mallee, SA.

A diversity of plant species has been introduced into New Zealand for amenity purposes and many of these now pose serious threats to forest remnants. The problems are usually greatest in remnants close to towns and roads,²³⁸ but increasingly problems are being seen right across rural New Zealand. Weed species include climbing plants such as old man's beard and banana passion vine, ground plants such as blackberry and wandering Jew, and shade-tolerant shrubs such as privet, elderberry and sycamore. These plants at their worst can result in canopy collapse and a total failure in regeneration, but because of the small size of many remnants it is practical to control most weed species. Control can involve both weeding and the use of herbicides, but because of the location of remnants in otherwise developed landscapes, and the ease with which both native and exotic birds disperse their seeds, ongoing vigilance is required to ensure that once removed they don't return.

Because of the effects of domestic stock and invasive species, another component of remnant management often involves restoration plantings. These may be undertaken to provide a buffer around a remnant, to enhance connectivity between remnants or to return species that have become locally rare or extinct. Control of invasive animals is essential for most restoration plantings. Often the aggressive introduced grass sward that develops after removal of livestock also needs to be controlled to allow restoration plantings to grow, although once established they will shade out grasses.

One of the biggest challenges for remnant management in New Zealand results from the dramatic changes that have occurred as a result of species invasions. Invasive plants and animals are often the dominant component of biodiversity across much of New Zealand and with the exception of a very few species, it is unlikely that they will be exterminated in the near future. Any cessation in invasive species control will result in the reinvasion of remnants by these species from surrounding areas and the loss of biodiversity values. Effective conservation management in the face of invasive species requires an on-going, perpetual, resource commitment.²³⁹



Fenced lowland forest remnant, Northland. Fencing out domestic livestock results in substantial improvements in understorey vegetation condition.



Vine of old man's beard climbing up into the canopy of a remnant kahikatea tree.

Grazing and woody weeds

Grazing can be an important tool for managing woody weeds that threaten native biodiversity in grasslands. However, rangeland grazing is a ‘two-edged sword’ – too much grazing can be detrimental to native biodiversity while too little grazing can be equally detrimental, leading to changes that lead to the loss of the same biodiversity values. While grazing removal can be advocated for conservation purposes, it can also result in a rapid expansion of woody weeds in some situations.

In the New Zealand high country, the dry and semi-continental basins and mountain ranges of the eastern South Island, Maori and European fires have removed the original woody vegetation.²⁴⁰ Early European pastoralists planted northern hemisphere conifers, especially pines, larch and Douglas fir, for shelter around homesteads and mustering huts, and a diversity of European plants in homestead gardens for their amenity values. Many of these exotic woody plants have subsequently spread from their planted locations, invading high country tussock grasslands especially in the absence of domestic grazing animals.

Browsing by Merinos has a major influence on the survival of young seedlings of exotic conifers (called ‘wildings’) that spread into tussock grasslands.²⁴¹ Grazing pressures of >0.5 Merino stock units/ha can significantly reduce seedling establishment and early growth rates, particularly where seed rain is light. But to be successful, wilding conifers must be browsed before they reach 2 years of age after which they become sufficiently woody and robust to make it difficult for animals to cause complete defoliation, and hence mortality. Palatability to

browsing animals also varies with species. Corsican pine is the least preferred and radiata pine the most preferred of the wilding conifers. Sheep are more effective in suppressing wildings than cattle, while the use of fertilisers to improve grassland productivity increases grazing levels and hence improves wilding control.

The rose, sweet briar, a native of Europe, was introduced to New Zealand as a garden ornamental and widely planted throughout the country. It has quickly spread from gardens because of the ready dispersal of rosehips by birds and livestock, and now occurs as an unwanted plant in modified and extensively grazed tussock grasslands.²⁴² Research in the upper Waitaki Valley, South Island, at sites with and without Merino



Wilding conifers (mainly Douglas fir) invading tussock grassland, Queenstown.

Effect of grazing on sweet briar average density, cover and height ($\pm$ standard error).

	Ungrazed	Grazed	<i>F</i>	<i>P</i>
Density (plants/m ²)	0.33 $\pm$ 0.05	0.13 $\pm$ 0.04	8.55	0.015
Cover (%)	0.44 $\pm$ 0.07	0.22 $\pm$ 0.05	6.19	0.032
Plant height (m)	0.52 $\pm$ 0.03	0.37 $\pm$ 0.04	7.93	0.018

grazing found that briar was significantly taller and had higher cover and densities in ungrazed sites than grazed sites.²⁴³ The total numbers of plants in all size classes were reduced with grazing, and there were proportionately more small (≤ 0.5 m high) plants and less large (> 0.5 m high) plants at grazed sites.

The results of both of these New Zealand high country studies suggest that grazing can suppress woody weeds, especially when occurring during the early stages of woody weed invasion. Consequently, grazing removal is likely to facilitate the expansion of woody weeds when seed sources are present, with detrimental impacts on other species through suppression and competition, including a number of nationally threatened herbaceous and woody native plant species.

A similar story is evident on the Northern Tablelands of NSW. If areas are fenced from livestock, for example to encourage woodland regeneration, they are prone to infestation by blackberry and sweet briar if seed sources are present. Both these species were introduced early in European settlement and have been declared noxious in the region. Livestock grazing is a good way of achieving partial control of these weeds, especially when they are in the early stages of invasion, although the effect of grazing on woodland restoration also needs to be considered.

Grazing in semi-arid areas can, however, promote woody weeds, especially where grazing reduces perennial grasses and promotes unpalatable grazing-tolerant shrubs in their place. This has occurred over the 75 000 km² of Cobar pediplain rangeland in western NSW over the past 150 years. The combined pressure of livestock, rabbit, kangaroo and feral goat grazing and periodic drought significantly reduced the abundance of native grasses and herbs, which were otherwise capable of outcompeting unpalatable native shrubs. Once the native grasses disappeared, the shrub seedlings were able to establish in high rainfall years. If not burnt or outcompeted at a young age, most of the woody weed species become basically indestructible to aboveground browsing,²⁴⁴ fire and slashing. The upper part of the soil profile in areas dominated by unpalatable shrubs is acidic,²⁴⁵ reducing herbaceous



Rosehips of sweet briar are readily dispersed by cattle and horses in the New Zealand high country.



Woody encroachment of native shrubs and trees, Cobar pediplain.

productivity, and grass growth is suppressed through competition. Unpalatable native shrubs (invasive scrub) are thus an important management problem in the Cobar region.

Clearly the relationship between grazing and woody weeds is not always straightforward. In many situations such as in the South Island high country, grazing can be used successfully to control the spread of woody weeds. However, grazing appears most useful during the early stages of woody weed invasion, and stocking rates need to be set considering the range of values present; grazing at too high a level while controlling invasive woody species will also result in unwanted impacts on native biodiversity.

Seasonal grazing

South Island high country farms are unique among New Zealand farming systems in that they are dominated by native vegetation, with stock management based on the seasonal movement of stock around the property. Merinos are the main livestock, although small numbers of cattle and deer are also grazed. Similar grazing management practices with cattle used to be applied in the Australian Alps before grazing was removed from state parks, although seasonal grazing is still undertaken in other mountain regions of the world (e.g. in central Asia and in the European Alps) where it is referred to as transhumance.

New Zealand high country properties are typically large (5000–40 000+ ha) and at relatively high altitudes (500–1500+ m). The vegetation is dominated by induced

and natural grasslands – woody vegetation is sparse as a result of 700 years of human impact, initially through Maori fires, and then as a result of fire, overgrazing and plagues of rabbits associated with the early stages of European settlement.²⁴⁶ The climate can be challenging, with hot dry summers and cold winters, and the growing season is usually short. Notwithstanding these constraints, biodiversity values are high. High country farming commenced in the 1850s and today's farmers have learnt from the mistakes of their forebears, with modern rangeland management typically conservative and more in balance with the constraints of the natural environment.

While high country vegetation is dominated by native plants, especially tussocks, a range of exotic plants are also



Central Otago high country property in late winter with lower slopes fertilised and over-sown and higher country used for summer grazing.

present including herbaceous and woody species. While some of these species have been deliberately introduced (e.g. as pasture or shelter) many have arrived of their own accord and some now threaten both economic and biodiversity values in these environments. A number of introduced animals, especially rabbits and hares, are also widespread through the high country and also threaten both economic and biodiversity values.

The key to successful management for both fine wool production and biodiversity in these environments is the seasonal grazing cycle. Typically, Merino ewes are kept on the lower country from lambing to weaning but are then moved up into the high country for 6–8 weeks in late summer (wethers usually go up earlier). They come back down to mid elevations in early winter (below the winter snow-line) and then down on to the lambing blocks again after spring shearing. On many properties, supplementary feed is provided for much of the winter period, usually being produced from cultivated and often irrigated flats over the summer. The best high country properties have a balance of cultivated flats, lambing country and summer country. Winter and lambing country has often been fertilised and over-sown with pasture grasses and legumes, but usually retains a significant component of native biodiversity, mainly tussocks and shrubs, while summer country is typically unimproved natural tall tussock grassland, often located above the natural elevational limit of tall woody vegetation.



A shearing shed in action. Fine wool production is the key to the success of high country properties.

This seasonal cycling of grazing is critical ecologically as it allows the lower country to be spelled through late summer, ensuring that there is sufficient biomass available to sustain the ewes through lambing but equally preventing overgrazing of the native biodiversity on this country during the driest part of the summer. Sheep typically feed on the over-sown element in these grasslands, but if pushed too hard they will start feeding on native species. Spelling these areas gives the native species the chance to flower and seed and plays a key role in their long-term persistence. Restricting grazing to a 6–8 week period in the natural high-altitude, tall-tussock grasslands reduces the impacts of livestock on these systems, leaving them ungrazed for much of the summer. However, the key to successful grazing across this whole system is conservative management. As Hugh Cameron, a highly successful high country farmer in the Waitaki Valley, points out, ‘If you were to push this country too hard, you would quickly lose both the economic potential of the grasslands and their outstanding natural values.’

Much of the high country land that is grazed in New Zealand is leasehold and there has been considerable pressure from both government agencies and conservation advocacy groups for some of this leasehold land to be surrendered, especially the higher altitude areas. In return farmers are able to freehold lower altitude parts of their property. While much of the drive for this is related to public access to



Merino ewes being mustered back from the high country at the end of summer.



Tall tussock grasslands in Merino summer grazing country, Waitaki Valley.

recreational opportunities, it is resulting in perverse outcomes for biodiversity conservation as farmers who have gone through tenure review are now intensifying the management of their new, usually lower-altitude, freehold land through extensive cultivation and irrigation resulting in significant biodiversity losses in these parts of the landscape.²⁴⁷ Ironically, the higher altitude areas are already well represented in the public conservation estate, while some of the highest biodiversity values occur at lower altitudes. Furthermore, removal of grazing from higher altitude grasslands results in the

expansion of woody weeds, such as wilding conifers, which then threaten the very biodiversity values that the tenure review is trying to preserve.²⁴⁸

While the seasonal grazing cycle is not perfect, if undertaken conservatively it plays an important role in sustaining native biodiversity values in these largely human-induced grassland and shrubland ecosystems. The key to successful rangeland management on these high country properties is maintaining balance between lower and higher country, and ensuring that all areas experience adequate periods of rest.

Grazing management to conserve understorey wildflowers

Anne Brown is a senior vegetation consultant with Greening Australia and has lived and worked in the Mid North of South Australia most of her life. In 1966, her father-in-law, Geoff Brown, was appointed officer-in-charge of Wirrabara Forest by the then SA Woods and Forests Department, and moved into the manager's residence at the Forest headquarters. Twenty years later, Anne's husband Chris became forest manager, and Anne and her husband moved into the manager's residence for 10 years before transferring to nearby Wirrabara township.

Wirrabara Forest is 674-mm rainfall country on the eastern slopes of the southern Flinders Ranges, and the fine eucalypt open-forest of sugar gum, SA blue

gum, river red gum and grey box encouraged the South Australian colonial government to establish a public forest there in the 1870s.

Fascinated by botany, Anne marvelled at the show of spring wildflowers in the grassy open-forest understorey in the large paddock behind the manager's residence, each year. From discussions with Geoff and her husband, Anne established that forest managers had grazed the grassy open-forest behind the Forest headquarters for a brief period in late spring and early summer each year, to reduce the fuel load and protect the buildings and associated public recreation infrastructure from wildfire during the summer–autumn fire season.

Sheep were depastured in the paddock in November and would stay until December or January depending on the season, until the grass was grazed down and the odour, dust and flies became too much for residents, staff and visitors. The paddock wasn't grazed at other times of the year. It is likely that this seasonal grazing regime was instituted soon after the Forest was gazetted, to protect the residences, offices and workshops and preserve local amenity.

The result of perhaps 140 years of late spring–early summer sheep grazing is the maintenance of a spectacular diversity of wildflowers in the grassy open-forest understorey. The reason is that by the time the sheep are put into the paddock, the spring flowering forbs have already flowered, seeded and, for species with annual aboveground shoots, started to senesce in most years. The sheep grazing has, if anything, a positive effect on the spring wildflowers because the sheep suppress later flowering herbs, such as the C_4 grasses (e.g. kangaroo grass) and low shrubs and woody seedlings that would otherwise compete with the wildflowers. Anne has worked for Greening Australia for 13 years and has combed the Mid North of SA for examples of grassy woodland and open-forest with understorey vegetation with a wildflower composition much like it would have been when Europeans first settled the region in the 1850s. She knows of only a handful of sites, mostly on public land, that compare



Box–gum grassy open-forest in the paddock behind the officer-in-charge's residence at Wirrabara Forest headquarters.



The grassy understorey at Wirrabara Forest covered in spring flowering herbs, including bulbine lilies, yam daisies, native buttercups, common vanilla lilies, scented sun orchids, scarlet runner, guinea flower, common eutaxia and mat-rush.

with the paddock behind the manager's residence in terms of herbaceous diversity and richness of grazing-sensitive wildflowers.

The vegetation of the paddock is grassy open-forest of box and gum to 25 m with a little drooping sheoak and native pine in the tree layer. Shrubs are sparse and have probably been suppressed by browsing sheep and macropods, particularly the leguminous shrubs and young casuarinas. Scattered native cherries, tea tree and wattles occur through the forest, as well as occasional heavily browsed leguminous shrubs such as common eutaxia and Australian indigo. The grass layer is dominated by annual and perennial C_3 grasses, including native wheat-grass and weeping rice-grass, introduced graminoids, common native herbs like wood sorrel and native geranium, and a diverse array of native herbaceous wildflowers.

What makes the herbaceous understorey really special is the many grazing-sensitive wildflowers that have been lost from woodland and open-forest grazed

year round, both throughout the region and, indeed, from similar vegetation throughout south-eastern Australia. Chief among the spring (October) flowering herbs are native buttercup, pink fairy, billy buttons (woollyheads), bulbine lily, scarlet runner, blue, white and pink sun orchids, yam daisy, hard mat-rush, stinking pennywort, common woodruff, pale sundew, common vanilla lily, twining glycine, guinea flowers and greenhood orchids.

The above species are all rare or absent from commercially grazed sites elsewhere in the region. By contrast, herbaceous weeds that are common in grazed areas disturbed by livestock are confined to just a few species in the Wirrabara Forest paddock. They include small areas of cape tulip and soursob in more disturbed parts of the paddock, and annual grasses like silver grass, which are thinly but more widely distributed. The lack of weeds like salvation jane and the absence of a dense layer of wild oats are another reason why this paddock is so special for nature conservation.



From left: Buttercup, blue sun orchid and pink caladenia.

This site demonstrates the importance of agricultural management in maintaining biodiversity values. Agricultural practices such as livestock grazing are strong filters on the native species that are able to persist in the landscape. By consistently varying management in different places, a mosaic of habitats is created suitable for different assemblages of plants and animals. Were the grazing management regime in this paddock ever to change, there is the risk that most of the grazing-

sensitive herbs in this regionally significant assemblage would decline or become locally extinct. Fortunately, for the time being, while Greening Australia's Anne Brown works steadily to increase awareness of biodiversity values in the community, this site looks as though it will continue to provide a spectacular glimpse of what spring time in south-eastern Australia grassy woodlands and open-forests used to be like.

Role of native biodiversity as shelter for lambing

Lambing is often seen as a ‘weak link’ in the meat and wool production system, as lamb mortality reduces the number of lambs available for meat processing and as replacements for the breeding flock, reducing farm profitability. A range of factors including breed, genetics, nutrition, lamb birth weight, number of lambs, mid-pregnancy shearing, behaviour and cold-starvation syndrome is known to adversely affect lamb survival, especially during the first few hours and days after birth.²⁴⁹ A major contributing factor to lamb mortality, especially in cooler climates, is a lack of shelter during windy, cold, wet weather. Lambs, especially in the first few days after birth, can quickly succumb to the effects of wind chill during adverse weather, while shelter can mitigate these impacts.²⁵⁰

While there has been debate among farmers and scientists about whether unshorn ewes seek shelter for

their lambs in bad weather,²⁵¹ research shows that ewes seek shelter more once they have lambs at foot than prior to birth, and that this behaviour decreases slowly as lambs age.²⁵² Traditional lambing shelter on Australian and New Zealand farms involves the use of shelterbelts, often comprising fast growing exotic tree species such as pines or cypresses, and there is an extensive literature on the benefits of this type of shelter for lambing.

Native biodiversity dispersed across paddocks, especially tussock grasses and shrubs, can also provide important diffuse shelter in lambing paddocks that has the potential to offset the impacts of adverse weather events.²⁵³ Such shelter is ‘free’ in that the tussocks or shrubs are already there and don’t require active planting, although appropriate management to ensure their continuing presence is required. This kind of shelter is particularly important in areas where it is



Shelterbelts, here consisting of exotic conifers, are the traditional form of shelter on farms.

difficult to establish traditional shelterbelts, where lambing blocks are large and hence the benefit of traditional paddock-edge shelterbelts is limited, or where establishing shelterbelts poses other risks, especially as a seed source for woody weeds (e.g. in the New Zealand high country). While native species such as tussock grasses are of much shorter stature than traditional shelter trees, they can still provide important shelter for lambing ewes.²⁵⁴

The importance of native plants in providing shelter for lambing is, however, based largely on anecdotal observations by farmers on enhanced lambing success in blocks with tussocks or native shrubs. For example, in a survey of Tasmanian pastoral sheep properties, several farmers commented on the value of tussocks and sagg (a grass-like perennial) for shelter during lambing.²⁵⁵ Similar observations have been made in New Zealand, where hill and high country farmers report that they typically put their twinning ewes in tussock blocks, as they are more likely to successfully raise both lambs than in more exposed open pasture-dominated blocks. However, care is required in using tussock blocks as they do not provide as much nutrition to lambing ewes as developed paddocks, with the maximum benefit for lambs being in the first couple of weeks after birth.



Merino ewes sheltering behind native red tussocks during strong winds and rain in the South Island high country.

Annabel Tripp and Roy Veronese farm Snowdon Station, a 2200-ha sheep and cattle property in inland Canterbury. The success of their stud Perendale flock is dependent on the presence of tussock blocks for lambing – they preferentially put their twinning ewes on some 600 ha of tussock grassland dominated by silver tussock, with some red tussock, with the remainder going on to 300 ha of bare paddocks. They achieve 180% lambing success from the ewes on the tussock blocks compared to 160% for ewes on the bare-paddock blocks. Annabel puts the difference down to the sheltering effect of the tussocks as the ewes are otherwise the same in terms of body weight and scanning results. However, careful management of the flock is required to do this with ewes flushed first on grass to increase body weight and only kept on the tussock blocks for the critical first few weeks of lambing before being moved back on to more nutritious grass-dominated paddocks. Care is also required in the subsequent management of the tussock blocks; overgrazing by cattle in particular can adversely affect tussock health. Annabel believes that the balance between the tussock blocks and pasture-dominated fertile flats is critical for the success of their farming business.

The increase in lambing success at Snowdon due to the presence of tussock shelter is substantial when



Shelterbelts, this one using native species of tree and shrub, are essential for decreasing sheep mortality and increasing lambing rates on the New England Tablelands as well as providing biodiversity benefits.



Silver tussocks with bare-pasture block and radiata pine shelterbelts behind, Snowdon Station.

compared with the results of contour planting on the New England Tablelands of NSW. Here double tree rows, one of radiata pine and one with native shrub and tree species, spaced 60 m apart and running along the contour resulted in a 50% reduction in Merino sheep death rates and a 10% improvement in lambing success over 15 years.²⁵⁶

Native shelter is of course also valuable for biodiversity conservation both in itself and through providing habitat for native animals such as insects and lizards.²⁵⁷ Tussock grasslands provide habitat for a wide range of other native plants and animals, and also have high aesthetic values. Shrubs are also important habitat for other native biodiversity. For example, in a rangeland system in southern New Zealand, native shrubs sustained higher native ground-dwelling invertebrate diversity than adjacent exotic pasture.²⁵⁸

Matagouri, a common shrub in New Zealand farmland, has been shown to provide important habitat for a range of invertebrates including natural enemies (e.g. spiders, ladybirds, parasitoid wasps) of several agricultural pests, as well as providing nectar resources for crop pollinators.²⁵⁹ Other native shrub species such as tree daisies are also important habitat for native invertebrates including many Lepidoptera. Native shrub and tussock shelter for biodiversity is most important where native biodiversity has declined substantially. Even patchy native shrubland in an otherwise exotic grassland environment is important for invertebrate biodiversity conservation, while also providing shelter for livestock. Thus, native biodiversity has the potential to provide 'win-win' outcomes for both farm production through reduced lamb mortality and biodiversity conservation, especially in hill and high country farms.

Native vegetation and natural pest control

Natural pest control is one of the major benefits of biodiversity in agricultural landscapes. It is estimated that parasites and predators in natural ecosystems provide an estimated US\$40 billion per year in benefits for pest control in crops in the USA. Without these natural enemies, crop losses by pests in agriculture would increase 10–20% and the amount of pesticide use and cost of chemical control would escalate.²⁶⁰ In Australia, natural pest control has attracted most interest among growers and scientists in the irrigated cropping and horticultural industries, because abundant water and fertiliser leads to ideal growing conditions for both crops and pests. Early attempts to grow cotton on the Ord River were aborted in 1973 due to the development of resistance to insecticides by pests and mounting insect pressure on crops.²⁶¹ Irrigated crops receive the highest and most costly inputs of pesticide. The cost of insecticide application on irrigated crops of conventional cotton (i.e. not genetically modified with

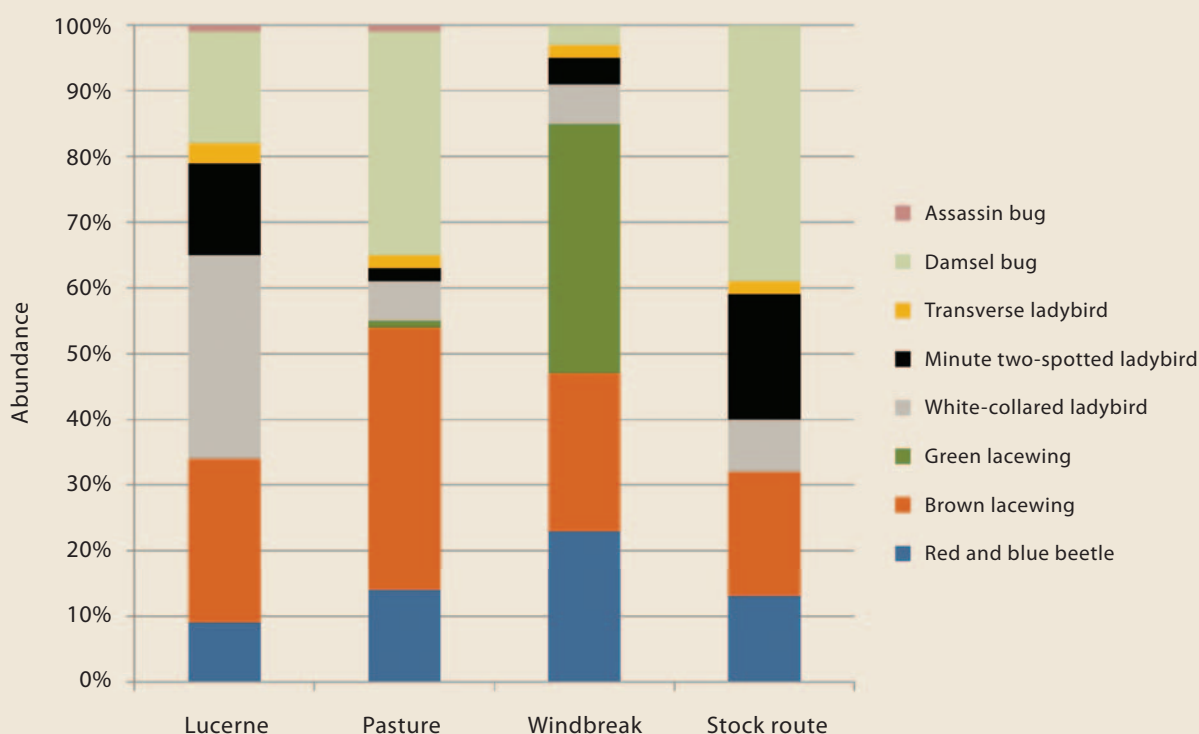
Bacillus thuringiensis genes) averages \$457/hectare in northern NSW, mainly due to the need to control *Helicoverpa* or cotton bollworm.²⁶² Insecticide costs in irrigated vegetable production range up to \$340/ha for lettuce and sweet corn production in NSW,²⁶³ and over \$300/ha in citrus production. Thus, major investments have been made in recent years to understand more about natural enemies and better manage natural pest control in agriculture.

University of New England researcher, Dr Ingrid Rencken, studied the population dynamics of natural predators in irrigated cotton on the Namoi River west of Maules Creek, north-west NSW, between 2002 and 2005.²⁶⁴ She was particularly interested in whether the generalist predators that occur in irrigated cotton also occur in nearby non-crop vegetation (e.g. native trees, grasses, shrubs and introduced weeds) and the role of native vegetation in harbouring natural enemies. The vegetation she studied included native pasture, open poplar box woodland with a weedy understorey (travelling stock route), dryland lucerne, riparian gallery forest of river red gum, and planted windbreaks of mixed native trees (planted in 1995 and consisting of various species of eucalypt, casuarina, melaleuca and acacia). The main predatory insects were damsel bugs; green and brown lacewings; transverse, minute two-spotted and white-collared ladybirds, and red and blue beetles. Ingrid sampled each of these vegetation types between July (winter) and February (summer) each year. Beneficial predators occurred in all vegetation types surrounding cotton fields, although insect species varied in abundance between habitats, months and years.

Habitat specialisation for overwintering and reproduction also varied among generalist predators. Ladybirds preferred to reproduce in dryland lucerne and to a lesser extent along the stock route. Lacewings tended to reproduce in the planted windbreaks. Damsel bug nymphs mainly occurred in pasture and to a lesser extent along the stock route. Rainfall and irrigation influenced predator numbers positively, while summer pesticide applications had a negative impact. All non-



One of the planted windbreaks of native trees and shrubs planted in 1995 and studied by Ingrid Rencken. An irrigation channel separated the track from the field on the right.

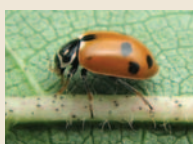


Red and blue beetles, brown lacewings and damsel bugs were found in all non-cotton habitats but were proportionately most abundant in planted windbreaks, pasture and along the stock route, respectively. Green lacewings were mainly found in planted windbreaks, white-collared ladybirds mainly in lucerne, and minute two-spotted ladybirds mainly in lucerne and along the stock route.

(Data courtesy of Ingrid Rencken; photos courtesy of Cheryl Mares, Lewis Wilson and David McClenaghan)



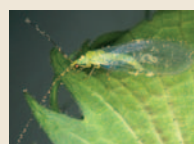
Damsel bug



White-collared ladybird



Minute two-spotted ladybird



Green lacewing



Brown lacewing



Red and blue beetle

cotton vegetation types were important in harbouring a suite of generalist predators and being a valuable source of predators.

A study at Boggabilla, NSW, showed that generalist predators move at least 10 km, their movements depending on pest pressure, spray activity and the spatial pattern of cotton and native vegetation. The mobility of predators means that growers need to think at a district-wide scale when considering habitat management and insecticide spraying decisions, not

just at the scale of habitats and fields on their own and their neighbours' properties. Maintenance of a variety of habitats, dominated variously by grasses, shrubs and trees, supports a range of predators, and habitat can be enhanced if the vegetation has access to water in dry times. Ingrid's study highlights the importance of managing non-crop vegetation within and surrounding cotton properties at farm and regional scale to maximise the benefits from improved pest control.

Conservation biological control in vineyards

Conservation biological control involves the protection and enhancement of the natural enemies of agricultural and horticultural pest species in order to reduce the abundance and impacts of these pests. Conservation biological control has been actively promoted as an alternative to the traditional use of pesticides in agriculture and horticulture and has been increasingly used in arable farming systems, for example through manipulating field margins or establishing flower strips²⁶⁵ and more recently in horticulture. This approach to pest control is thought to work primarily because the numbers or efficiencies of natural enemies (predators and parasitoids) are enhanced through the establishment of vegetation which provides key resources (e.g. shelter or nectar) for these species.²⁶⁶ From a biodiversity conservation perspective, conservation biological control is particularly advantageous when it involves both native plant species as the resource base and native predators, especially when such species are otherwise scarce or absent in the landscape.



Waipara vineyards in autumn.

The New Zealand wine industry has been promoting New Zealand wines internationally as a high quality product produced using sustainable practices and building on New Zealand's 'clean green' image. Wine growers in the Waipara district of Canterbury have been participating in the 'Greening Waipara' project²⁶⁷ which seeks to re-establish native biodiversity within the Waipara landscape and to increase sustainable agricultural practices. The Waipara district was originally covered in extensive forests, woodlands and shrublands but early Polynesian burning and more recent European farming have resulted in the loss of most native biodiversity, replaced by pasture and crops, and most recently vineyards. The vineyards participating in the Greening Waipara project see this as providing them with a potential marketing advantage – by combining sustainable environmental practices with quality wines the Waipara vineyards hoped to gain a unique marketing brand that would aid both domestic and international sales. This is particularly important as New Zealand supplies <2% of the world's wine, yet has an 18% share of the high-end wine market. Consumers of high-value products are often the most sensitive to the environmental sustainability of product production.

The biological control of vineyard pests has been common practice for many years, with roses often planted at the ends of vine rows and plants such as buckwheat planted between rows to facilitate the abundance of natural predators of vineyard pests. In the Greening Waipara project, native New Zealand plants are being used for this role, thus increasing native plant biodiversity within the landscape. At vineyards such as Mud House Winery native woody species have been established in blocks of mixed plantings adjacent to vines, while native jasmine vine is being used at the end of vine rows and various native herbs and subshrubs planted under the rows. All of these plantings are designed to increase the number of predators of vineyard pests such as the leaf-roller larvae of the light-brown apple moth and when planted under vine rows to suppress weed species.



Native everlasting daisy that has been planted below the vines to attract predatory insects that control vine pest species. (Photo: Jean-Marie Tompkins)



Biodiversity trail with restoration plantings and interpretation panels, Torlesse Wines vineyard.

Biodiversity trails have also been established at several vineyards. Visitors to the wineries can follow these trails through areas of native restoration and walk among the vine rows with native plants. Panels explaining both the ecology of the plants and their role in the vineyards provide further information to visitors. At Mud House Winery, the trail leads directly out from the café and cellar providing an additional point of interest to winery visitors.

Initial research results²⁶⁸ suggest that while floral resources vary among the native plants tested, several native species significantly enhance the longevity of key predators of vineyard pest species. Furthermore, native plantings under vines also increase the abundance of predatory spiders, key predators of pests, presumably because the plantings provide shelter and alternative food sources compared to the bare ground that would normally be present. Weed densities are also lower under native plantings than in non-planted strips.

While the costs of establishing native plants are quite high, with good pre- and post-planting maintenance (e.g. mulching and weed control), their long-term survival is good. Protecting remnant patches of native shrubland adjacent to vineyards is also likely to increase the habitat for predators.

Jean Luc Dufour, the manager at Mud House Wines' 50-ha Waipara vineyard, is enthusiastic about the potential role of native plants for facilitating conservation biological control. While only a proportion of the vineyard has been established in native plants he is keen to expand this area and is especially enthusiastic about the potential of this approach to reduce the reliance on herbicides and pesticides in vineyard management. He sees a distinct marketing advantage for their product arising from this work and plans to expand the area of the vineyard with native plants as funds become available.

Pasture cropping and no-kill cropping

Pasture cropping and no-kill cropping involve over-sowing crops into living (native) perennial pastures. Both take advantage of the fact that crops can be grown in grazed pastures without the need to remove the pasture or fallow the soil. Pasture cropping involves no-till sowing of crops into dormant pastures once soil moisture levels have built up. No-kill cropping involves dry sowing using a zero-till (coulters type) implement prior to rain.

Pasture cropping

Col Seis and Daryl Cluff came up with the idea of pasture cropping and developed it in the Gulgong district on the central slopes of NSW in the early 1990s.²⁶⁹ Col and his son Nicholas' 840-ha property, 'Winona', has been family owned and operated for the past 150 years. By the 1970s, the family recognised the need for change due to unsustainable farming practices. The annual-based production system had become dependent on high inputs but was declining in productivity and profitability,



Col Seis at Winona. (Photo courtesy of Col Seis)

and suffered ongoing problems with insect attack and fungal disease in crops.²⁷⁰ The granite soils had become compacted, lacked structure, were acidic, high in aluminium and had organic carbon levels below 1.5%. The topsoil had declined to less than 100 mm deep and the subsoil was sodic. The poorly structured soil allowed little water to infiltrate and there was consequently little nutrient cycling. Saline areas first noticed on Winona in the 1920s had expanded to cover over 40 ha by the 1970s.

A bushfire in 1979 was both a disaster and an opportunity to rethink the farm plan. To reduce costs and help drought-proof the farm, Col shifted from a dryland cereal-based production system to a grazing enterprise with a native perennial pasture base dominated by the locally occurring, summer-active redgrass. With a little more thinking outside the box, Col and Daryl hit on the idea of combining summer-active pastures and winter-active cereals in the one paddock. Coupled with time-controlled grazing, which Col introduced in the 1990s, pasture cropping and grazing management have been able to restore the productivity and profitability of Winona, with less inputs.

Crops are grown once the redgrass pasture has gone dormant in the late summer–autumn and sufficient rain has fallen to fill the profile. The major advantage of this holistic approach to grazing and cropping is that pastures can be grazed up to the day the paddock is sown and returned to grazing immediately after harvest. The system uses less (or no) herbicide than traditional cropping systems, as crops are sown into dormant pasture, without the need to maintain a fallow.

According to Col, 'Agriculture and ecological function can and must function together. Grazing is an essential part of pasture cropping. At Winona, we graze sheep or cattle to manage our native grasslands during the time when crops are not planted, as well as to prepare paddocks for pasture cropping. The livestock mulch and manure paddocks prior to sowing, reduce the bulk of pasture to prevent shading of the crop, and prune the roots of the perennial grasses. This preserves moisture and nitrogen for the crop.'



Oats being harvested in early summer in a pasture-cropped paddock dominated by redgrass and other C_4 grasses. (Photo courtesy of Col Seis)



The soil profile to 50 cm depth of the Winona paddock (left) and neighbouring paddock, which were studied by University of Sydney researchers. (Photo courtesy of Col Seis)

Measurements by CSIRO's Dr Sarah Bruce at Winona in 2003–05 demonstrated improvements in soil health, water and nitrogen use efficiency and ecosystem function over a 16-month period.²⁷¹ Large increases in soil carbon were measured. The combination of summer-active pasture and winter-active crop means higher useful biomass production over the year, greater use of soil moisture, more even use of soil nitrogen, and potentially less deep drainage and soil acidification.

A recent study by the University of Sydney's Peter Ampt, Rebecca Cross and Sarah Doornbos compared a paddock on Winona with an adjacent paddock on a neighbouring property in a cross-fence contrast. The Winona paddock was pasture cropped in 2000 (wheat), 2004 (oats) and 2009 (cereal rye) and was otherwise time-control-grazed by Merino ewes with graze periods of 2–3 days and recovery periods of 90–120 days for the past 20 years. The neighbour's paddock was sown to oats in 2000, 2004 and 2009 using disc ploughing, scarifying once and cultivating twice, and was otherwise set-stocked with sheep. The only fertiliser applied to either paddock in the 10 years prior to the study was with crops: 40 kg/ha DAP on Winona and 60 kg/ha

DAP on the neighbouring farm. No lime was applied to either paddock.

Despite similar crop yields in the two paddocks, other differences were marked (see table below).

Pasture cropping has led to an increase in the diversity of native pasture species at Winona. Col observes that 'redgrass was the only species I had when I first started developing pasture cropping in 1993. Winona pastures now contain over 50 native species. We are pasture cropping into about 20 species of summer growing C_4 species as well as redgrass. Pasture cropping encourages a range of perennial grasses to recruit or germinate

Comparison of pasture and soils either side of the boundary fence at Winona.

Variable	Winona	Neighbour
Cover of native perennial grasses (%)	83	11
Stocking rate (DSE/ha)	8.0	3.7
Soil organic carbon (t/ha to 50 cm depth)	90.1	43.4
Topsoil depth (mm)	457	100

from seed. It is used around the world now to restore grasslands and improve pasture species diversity.'

The more efficient use of land and reduction in costs make pasture cropping profitable, while the reduction in land degradation problems helps make the system more sustainable. Cereal yields are generally comparable to traditional methods, provided sufficient rain falls to fill the profile and there is follow-up rain to sustain the crop. The only issue is winter weed competition with the cereal crop. The stronger the redgrass pasture, the less room for winter weeds. Sometimes, paddocks have been sprayed with a knock-down herbicide like glyphosate once the summer-active pasture has gone dormant, but it is not recommended because of the resultant loss of winter-active perennial grasses. Alternatively, a selective broadleaf herbicide may be used to control winter weeds prior to sowing. Conventional fertilisers may be used to manage crop nutrition. However, with rising soil organic carbon and groundcover levels, many crops at Winona are now sown without fertiliser. Once complete groundcover is achieved, pasture cropping can be used to grow organic crops. This can be done without using a plough or herbicide to destroy the existing pasture.

The table below shows the difference in money spent today compared to 20–30 years earlier when Winona was managed under a high-input agricultural system.²⁷² (The costs have been converted to A\$2011 values.)

Comparison of the money spent on Winona managing a high-input mixed-farming system (1960–1992) and one based on pasture cropping (1993–2011).

Variable	1960–1992	1993–2011	Difference
Superphosphate on pasture	\$51 000	\$0	\$51 000
Sheep veterinary costs	\$12 000	\$7000	\$5000
Pasture seed and pasture establishment	\$5500	\$0	\$5500
Cropping expenses (200 ha)	\$40 000	\$20 000	\$20 000
Annual saving at Winona (840 ha)			\$81 500

Col estimates that at least 2000 farmers in every Australian state have experimented with pasture cropping or elements of it, from Geraldton, WA, to Biloela, Queensland.

No-kill cropping

Bruce Maynard invented no-kill cropping at the 1500-ha family property, Willydah (see p. 178), near Narromine, NSW, in 1996. No-kill cropping involves sowing cereals directly into pasture or grassland with zero disturbance, no fallow period and using livestock for fertiliser and nutrient recycling.²⁷³ Bruce sows dry when the soil is most capable of withstanding compaction by farm machinery and uses a coulter disc to cut a knife-like slot in the soil for the seed rather than a tine, minimising pasture damage. He does not use herbicides or fertiliser, relying on livestock dung and urine for nutrient inputs. Rotational (time-control) grazing may be used to reduce pasture biomass prior to sowing.

No-kill cropping is excellent for rehabilitating unproductive soils that have sealed or are biologically inactive. Organic matter is increased above and belowground by the growth of the crop and subsequent decomposition of residues, enhancing soil productivity, and returning a profit while undertaking restoration at the same time. Existing methods usually entail substantial cost and sometimes offer no prospect of economic returns in either the short or long term.



Sowing a no-kill crop at Willydah. (Photo courtesy of Bruce Maynard)



Monitoring a no-kill crop of oats in old man saltbush alleys at Willydah in November 2007. (Photo: Bruce Maynard)

The decision to use no-kill cropping or pasture cropping is really a decision about whether pasture disturbance is required. If a paddock is degraded and the soil needs rehabilitating without damaging the pasture that is already present, no-kill cropping can regenerate the site and improve soil and plant productivity faster than leaving it to mend itself or with livestock. If pasture cover is high but productivity low, pasture cropping can disturb the soil and pasture, add nutrients and unlock soil and plant production. Both techniques allow productive annuals to be reintroduced into dormant or unproductive pastures, to harvest crops, increase grazing production, or both. Pasture cropping has more tools in the toolbox than no-kill cropping. Pasture cropping leaves managers with greater control because fertilisers, pasture disturbance and pesticides are all potentially in play. No-kill cropping is more reliant on factors outside the farmer's control, but at the same time, it is hard to do the wrong thing with no-kill.

One of the attractions of no-kill cropping is low cost. Bruce can sow a grassland paddock to oats using a rig



No-kill sown millet and lablab in a degraded pasture in January 2010. (Photo courtesy of Bruce Maynard)

with 12 coulter units towed by the farm ute for \$12–17 per hectare, including seed (but excluding labour). In an 'ordinary' year in 2007, he harvested 1 tonne of oats per hectare compared to a conventional farmer down the road who achieved 1.5 tonnes but at considerably greater cost. Although most pasture cropping and no-kill cropping have focused on sowing winter cereals into dormant summer-active pastures, millet and lablab can be sown as a summer crop to beat annual weeds in degraded pastures. The millet can reshoot the following summer, stretching the economic benefits further.

One of the many positives about no-kill cropping is that it can be undertaken on soils and slopes that would be too risky to disturb using pasture cropping or conventional methods. Per hectare returns from pasture and no-kill cropping can be comparable with broadacre cropping, because grazing can occur most of the year while still achieving harvestable yields from grain crops growing through pasture.

Re-establishing native forest for conservation

One method that is widely used to enhance biodiversity values in farmland is to re-establish new individuals of plants and animals that have been lost or severely reduced in abundance at a site. Restoration plantings can be undertaken for a range of reasons including to buffer existing remnants, enhance connectivity between remnants, increase the total area of native habitat, provide habitat for natural pest control agents, or to reintroduce locally extinct species.²⁷⁴ For vegetation, restoration usually involves planting or direct-seeding desired species. However, in many instances it may be sufficient to simply remove grazing pressure. So long as seed sources are in close proximity and the extant vegetation does not limit establishment, native species will re-establish naturally – this latter approach has been termed minimum interference management²⁷⁵ or natural regeneration.

While relatively straight forward there are a number of issues that need to be considered in implementing

restoration projects that, if given proper attention at the outset of the project, are likely to greatly increase success. It is important to be clear what factors have led to the degradation and to make sure that these have been addressed.²⁷⁶ For example, if the key degrading factor was grazing, then removing grazing pressure (e.g. by fencing out domestic livestock) may be sufficient to ensure restoration success. However, in other situations, degrading factors might be more difficult to reverse (e.g. soil compaction) and may require a more intensive approach than would otherwise be the case (e.g. ripping the soil prior to planting). In some situations, removing the initial degrading factor may create additional problems which need to be addressed. For example, removal of grazing animals from sites that have a long history of fertiliser application more often than not results in the establishment of a rank sward of exotic grasses. Restoration therefore needs to address this through appropriate pre- and post-planting weed control (e.g.



Five-year old forest restoration planting in a former pasture site in North Canterbury.



Natural regeneration of kanuka in exotic grassland from adjacent mature plants after removal of livestock grazing in New Zealand.



Good nursery practice including inoculation with appropriate mycorrhizal fungi is essential for restoration success.

using herbicide or mulch) or through measures aimed at reducing soil nutrient levels (e.g. addition of bark chips or scarifying the soil), in addition to controlling the original degrading factor.

Species choice is also an important consideration. While the restoration goal might be to establish rainforest, planting of mature rainforest species into pasture sites (e.g. rimu and tawa in New Zealand or red cedar and rosewood in eastern Australia) might not be appropriate in some situations (e.g. sites prone to frost) and a better approach would be to establish seral species such as kanuka and manuka or blackwood (sally wattle) and tea tree, respectively. The use of seral species in rainforest restoration is common in New Zealand and Australia and as long as a seed source is present, later canopy dominants usually establish readily.²⁷⁷ However, for other forest types (e.g. beech or eucalypt forests) and for rainforest in frost-free sites, planting directly into open sites works well so long as there is adequate weed control. In much of Australia, planted eucalypt species establish readily in pasture, whether planted for restoration purposes or as shelterbelts, except where high soil nutrient and herbivorous insect levels result in defoliation or weeds are not controlled. The best guide

to species choice is usually to see what is happening at sites where regeneration is occurring naturally. Another consideration is the origin of the plant material, with the usual convention being to source plants from sites close and similar to the restoration sites. Some plant nurseries now specialise in eco-sourced plants to meet this need. In order to ensure a wide genetic base and fit planting stock, seed should be sourced from many healthy plants in the local area. Because of the risk of too narrow a genetic base in planting stock and the possibility that rapid climate change will drive local populations to extinction, some authors are now recommending ‘composite provenancing’ for restoration plantings, where most material is collected locally from genetically healthy stock, but some is collected at increasing distance from the site and perhaps 10–30% of material is collected much further afield.²⁷⁸

Consideration of mycorrhizal fungal associations is also important. For many woody plants, mycorrhizal fungi are essential to ensure establishment success and rapid growth as they assist in nutrient uptake and provide some pathogen protection. However, the correct mycorrhizas need to be present – with endomycorrhizas favouring some plant groups and ectomycorrhizas other groups.

The timing of planting also has an important influence on restoration success. In New Zealand, the best time to establish restoration plantings is spring, after the last of the severe winter frosts but before summer soil moisture deficits develop. Similar considerations also apply in Australia. With direct seeding, sowing prior to winter might be required to ensure that seed are properly scarified over the winter and can then germinate as soon as conditions become suitable in spring. A final factor for restoration success is to make sure that appropriate post-planting maintenance is undertaken. This involves ensuring that grazing animals continue to be excluded from the site – even one cow can destroy many thousands of dollars of plants and many hours of hard work in a very short period of time! Ongoing control of plant and animal pests is essential. Where restoration occurs on fertile soils with good soil moisture, ongoing control of grass and broadleaved weeds is essential until plants are big enough to overtop and suppress them.

The actual approach adopted for restoration will depend on the local situation, especially the availability of seed sources and the nature of the site to be restored, as well as the resources (financial and labour) available to undertake the required work. Natural regeneration will work best at sites where seed sources are in close proximity, while the planting of nursery-raised seedlings is likely to be more appropriate at sites where local conditions limit the likelihood of natural regeneration (e.g. seed sources are distant). In some instances, a mix of approaches might be used. For example at a 400-ha restoration site on abandoned farmland in North Canterbury, New Zealand,²⁷⁹ the main approach to restoration is natural regeneration which is being facilitated by exclusion of domestic livestock and control of feral animals. However, restoration plantings are also being used to enhance connectivity between existing forest remnants, and to reintroduce key food sources (harakeke [native flax] and kowhai [tree]) for native birds and locally absent or rare species (e.g. lowland totara [conifer]).



Good control of pasture grasses is essential for successful restoration.



Wetland restoration planting of harakeke (New Zealand flax) and cabbage trees provides an important food source for native birds such as tui, Northland.

Several of the case studies in the next chapter profile landowners who are restoring or managing restored native woodland and forest on their properties.

Broadacre revegetation – philanthropy and Cygnet Park Sanctuary

Native vegetation clearance in the wheat–sheep belt of southern and eastern Australia has contributed to the decline of native flora and fauna, and further species losses are predicted due to the extent of habitat loss.²⁸⁰ A 1999 report identified 20 woodland bird species that have declined in the wheat–sheep belt of NSW in the past few decades,²⁸¹ and a landmark 2009 study detailed the regional collapse of the avifauna associated with the fragmented box–ironbark forests and woodlands of northern Victoria.²⁸² On Kangaroo Island in South Australia, habitat loss and fragmentation is a key reason for the decline of seven nationally threatened plant species and more than 20 state and regionally listed plant species.²⁸³

In order to stem the tide, Californian philanthropists, Jack May and Hilary Austen, purchased 300 ha at Cygnet River, near Kingscote, Kangaroo Island, in 2001 as part of a broader vision to re-establish native vegetation and habitat across rural Australia and secure biodiversity assets for future generations. They called the area Cygnet Park Sanctuary, and now own it in partnership with Nature Foundation SA and David and Penny Paton of Adelaide, SA.

Cygnet Park Sanctuary is bisected by the Cygnet River and associated billabongs, which are lined by tall gallery forest of river red gum, SA blue gum and sugar gum. Scattered manna gums dot the adjacent floodplain. Strips

and patches of other native vegetation exist away from the river, including pink gum, Kangaroo Island mallee and peppermint box. Small numbers of several threatened plant species occur on the property including small-flowered daisy-bush (nationally endangered), Kangaroo Island pomaderris and MacGillivray's spyradium (both nationally vulnerable). At least one pair of glossy black cockatoos (nationally endangered) breeds on the property.

In 2003, the owners of the property formed a partnership with the Kangaroo Island Nationally Threatened Plant Project (KINTPP), a program initiated, managed and supported by the SA Department of Environment and Natural Resources (DENR) and the Kangaroo Island Natural Resources Management Board. Under this partnership, in excess of 300 000 seedlings of 120 species of native trees, shrubs, forbs and grasses have been planted since 2004 over about 200 ha of the Sanctuary in a series of experiments involving various pre-planting and establishment techniques. Experiments have focused on effective means of controlling weeds and native herbivore grazing, propagating an extensive suite of species, allocating species to different habitats, and different ways of obtaining varying densities and structures of plant species to best replicate natural ecosystems. These experiments were based on criticisms of earlier mass revegetation efforts – namely, the even-aged nature of the revegetation in straight lines, the



Cygnet Park Sanctuary sign, main gate. (Photo: David Taylor)



Broad-scale revegetation at Cygnet Park Sanctuary 3 years after the area was planted in 2008. (Photo: David Taylor)



Plantings of scattered eucalypts protected from browsing animals with cages on the fertile floodplain at Cygnet River, which is in the background lined with gallery forest.

regular spacing between rows, the random assortment of species within rows irrespective of soils and topography, and the restriction of plants to just a few species of tree and shrub.

In addition to the revegetation experiments, the plantings at Cygnet Park have established additional populations of the threatened plants mentioned above, as well as a stand of drooping sheoak that is now used by

glossy black cockatoos as food trees. In all, the plantings include five nationally threatened species and a large number of endemic, state and regionally listed plant species that are declining on eastern Kangaroo Island, an extraordinary restoration achievement.

The property owners have spent in excess of \$300 000, renovating the cottage, establishing a plant nursery (capacity for 100 000 tubestock seedlings) and sheds, and helping with fencing. Some 11 km of electric fencing have been erected since 2004 to exclude livestock, possums, kangaroos and wallabies. External funding has also been critical to the success of Cygnet Park and was sourced through KIN TPP to facilitate seed collection, propagation, site preparation, planting and ongoing management actions. This project has also funded experimental burns and coppicing experiments at Cygnet Park and elsewhere to stimulate the regeneration of degraded remnant vegetation. Cygnet Park has also become a base for the propagation of seedlings for habitat re-establishment projects on nearby properties, with more than 100 000 seedlings being propagated for this purpose since 2004.



The nursery at Cygnet Park Sanctuary. (Photo: David Taylor)

Along with DENR and the Kangaroo Island NRM Board, several additional organisations have played a key role in supporting the revegetation of Cygnet Park. These include the University of Adelaide's School of Earth and Environmental Sciences, the Woods Institute for the Environment at Stanford University, Unilife at the University of South Australia, Conservation Volunteers Australia, the Native Vegetation Council and the Australian government. This support has included participating in the annual Kangaroo Island Planting Festival, an event that has been developed on Cygnet Park and is designed to bring a large number of volunteers together for a short period of time to make a difference at a landscape scale. In 2011, more than 700 people attended the festival over a 3-day period and planted 120 000 seedlings over a 52-ha area.

In 2008, several of the owners of Cygnet Park Sanctuary and collaborators established BIO-R. BIO-R is an Australian, not-for-profit organisation developing innovative ways to facilitate private and public sector investment in effective conservation to address the lack of



Volunteers planting a revegetation experiment at Cygnet Park at the 2010 planting festival. This experiment removed the weed-infested topsoil (using a grader), and planted seedlings and seeds directly into uncontaminated soil. The mounds are the stockpiles of topsoil left by the grader. (Photo: Penny Paton)

habitat (i.e. the root cause of biodiversity decline). Such innovation will be needed, sooner rather than later, if the global extinction spasm underway is to be tempered.



Aerial view of Cygnet Park Sanctuary, showing remnant woodland mainly along the Cygnet River meandering east–west, other remnant vegetation away from the river, and the areas that were revegetated between 2004 and 2011 (red). (Image courtesy of David Taylor, SA DENR).

Old man saltbush plantings

Paddocks of old man saltbush and pasture alleys are a feature of Bruce and Roz Maynards' 1500-ha grazing operation at Willydah, Narromine, NSW (p. 178). Block plantings of saltbush were one of the first innovations they implemented on the farm in 1990, but they soon progressed to alley farming with pasture lanes between the saltbush rows. By 2005, the Maynards had planted paddocks out to saltbush in spirals. Today, if you were to jam all the saltbush rows together, 10% of the area of the property is under saltbush. But because of the alley configuration of most of the saltbush plantings, about 25% of paddocks have saltbush in some layout or other (blocks, alleys, spirals, concentric 'target' plantings, single rows, etc.).

Why plant shrubs in the Central West of NSW for a predominantly beef cattle and meat sheep operation? Drought-tolerant forage shrubs provide protein-rich

feed in dry times, permitting more stable production. Trees and tall shrubs like old man saltbush provide shade and shelter benefits for livestock and pastures under extreme weather conditions, and the yearlong metabolic activity of woody plants provides a constant habitat for soil microbes and fauna. The deep roots produce a fertile island effect, meaning greater nutrient availability for pasture species at the canopy edge. All of which adds up to a more resilient farm ecosystem and business.

Why old man saltbush? It is a local shrub that is native to the region, is easy to plant and establish, grows well, is reasonably long-lived and drought-resistant, and produces dense edible leaf from ground level to about 2–3 m height, thus providing plenty of shade and shelter for pastures and livestock in addition to feed. A local company produces cheap saltbush 'speedlings' (tiny seedlings with air-pruned roots in trays), so old man



Old man saltbush planted in an alley configuration at Willydah. (Photo courtesy of Bruce and Roz Maynard)



Old man saltbush planted in circles at Willydah. (Photo courtesy of Bruce and Roz Maynard)

saltbush meets all of the Maynards' requirements. The decision to plant saltbush rows in concentric circles ('targets') and spirals rather than straight lines was predicated on not having to decide which way the wind would blow or which time of day or season was more important in terms of the angle of the sun.

Preparations for planting old man saltbush begin 6–12 months beforehand by deep ripping the planting lines, which are then long fallowed with glyphosate to 1 m either side of the ripline. Three rows of saltbush, 2 m between the rows and 1.5 m in the row, are planted to allow for occasional plant deaths and still provide good shelter, leaving a 20-m pasture alleyway before the next saltbush row. Immediately before planting (1–2 weeks), the planting lines are rotary-hoed to a fine tilth. Planting only occurs on a full moisture profile. A vegetable transplanter with a water injection system (1.5 L per speedling) is hired for planting.

'The machine planter does a beautiful job so you can put the plants in and walk away,' says Bruce. 'Some people spray over the top with dilute glyphosate to maintain weed control and maximise growth because old man saltbush is resistant, but I prefer not to because



The vegetable transplanter on its trailer being towed into the paddock, ready for planting old man saltbush at Willydah. (Photo: Bruce Maynard)

I don't want the bare ground alongside the bush rows to turn into scalds long term.'

A well established new stand of saltbush can be grazed 6–12 months after planting for the first time, although at the height of the millennium drought, one planting had to be left for 3 years. Bruce trains the stock to keep the saltbush within browsing height rather than waste energy and money on slashing. Trained stress-

free sheep and cattle are adept at pulling down 2-m high branches, and eat a considerable amount of bush in both wet times and dry. Trained stock eat from the top whereas untrained sheep browse from below, causing problems. Bruce is adamant about not compromising the pasture layer in order to prune the shrubs.

In retrospect, taking 35% of the grazeable area of the property out of production by planting old man saltbush and trees in the worst drought (2002–2008) in history wasn't the best business move. However, the severity of the drought reinforced the need in Bruce's mind for shade and shelter to sustain production and the benefits of woody-grass edges for biodiverse pastures throughout the farm. The fact that the Maynard family was able to build their farm capacity at a time of weakness rather than strength reassures Bruce that they are building a resilient agricultural system for the future, come what may.

It has only been in the past year or so that the Maynards' 20-year investment in saltbush has had a significant positive impact on the farm business. CSIRO modelling suggests that 10% of a property should be under shrubs to obtain a large enough total area and sufficient paddocks for the investment to be economic. The Maynards' saltbush plantings are now mature and extensive enough to provide sustained feed and shade and shelter in both wet times and drought, and allow the flexibility to buy stock when prices are cheapest.



Old man saltbush rows neatly pruned by trained livestock at Willydah, despite abundant herbage after perhaps the two best consecutive seasons in 100 years.

Wildlife appreciate the investment, because fairy-wrens have colonised the saltbush paddocks in the past couple of years for the first time, and zebra finches and robins often play along the saltbush-lined laneways. In South Australia, formal surveys have shown that more bird species occur in old man saltbush plantings than adjacent pasture in the Murray Mallee, including chenopod shrubland specialists like white-winged fairy-wrens and orange and white-fronted chats.²⁸⁴



White-winged fairy-wrens, like this male (left), and orange chats have been found in SA Murray Mallee plantings of old man saltbush. (Photos: Lydia Paton)

Grassland restoration

In this section, we profile two contrasting ways of regenerating native pastures on alluvial clay floodplain soils in north-west NSW. Both methods have proven equally successful for the farming families involved. Doubtless there are additional approaches, as well.

Natural regeneration of grassland at Malgarai

Richard and Janet Doyle own 'Malgarai', 3200 ha of floodplain farming country 7 km east of Boggabilla, NSW. Richard's family purchased the farm and adjacent land in 1926. Malgarai consists of two blocks of cracking clay soils: 450 ha along the Macintyre River and the balance along the nearby Whalan Creek between the Bruxner and Newell highways. The mean annual rainfall is 615 mm.

Richard and Janet's vision for Malgarai is of a healthy farm environment supporting a vibrant, profitable grazing and cropping business, one that is continually regenerating and sustainable in perpetuity. After some

difficult years running a mixed cropping and grazing business and cropping up to 50% of the farm, regenerating their farm's soil and perennial pasture base has become the Doyles' number one goal.

Richard and Janet have struggled with conventional cropping as a business, a lifestyle and a land use. 'We were dissatisfied with both the life we were leading and what we were doing to the environment,' Richard admits. 'We made no money out of cropping, particularly over the last 10 years of drought, and so we had to question what we were doing and why. Our farmed country was down in organic matter, there were physical constraints, increasing sodicity problems, mineral imbalances, and the soil was biologically pretty unhealthy.' Richard and Janet were also dissatisfied with their grazing enterprise. The native pastures had deteriorated from continuous grazing and groundcover was often low, particularly along Whalan Creek, which was used to water stock.



Cracking clay soils were relatively unproductive after decades of conventional farming. (Photo courtesy of Janet and Richard Doyle)

After several years experimenting with grazing management, Richard and Janet moved to time-controlled cell grazing and a cattle trading operation in 2003, allowing them to adjust stocking rate according to seasonal conditions. The trade cattle (mostly steers) are either entirely grass-fed or grazed on winter forage crops and summer grass pastures for turn-off to feedlots. The grazing country has been subdivided into 30-ha paddocks and bore water piped to paddocks. Cattle were moved off the creek to maintain bank stability and restore vegetation cover.

How to regenerate pasture?

In moving from cropping to grazing, the Doyles were presented with the problem of how to turn cropping country into productive perennial pasture quickly, while maintaining cash flow in the midst of a long-term drought. They experimented with sowing perennial pastures, pasture cropping and allowing nature to take its course with natural plant succession.

Of these three options, natural regeneration of native pasture was the most successful and cost-effective. The Doyles were pleasantly surprised how quickly palatable perennial grasses returned to most of their retired cropping paddocks with appropriate grazing

management, and how productive many of the weedy pioneer plants proved to be in the first 2–3 years.

What they found by letting cropping country go back to nature in the first year was a lot of bare ground and weedy pioneers, such as rolypoly, vines, fleabane and early successional saltbushes (i.e. Mueller's saltbush, creeping saltbush and climbing saltbush). Richard was mortified when he first saw the weeds because they were not preferred forage species and he used to spend a lot of time and money spraying them out.

The Doyles learnt that the weedy colonisers were just a phase you have to go through. 'If the soil conditions aren't right, the system is not ready for the palatable perennial grasses, which are the more desirable, higher successional species,' observes Richard.

They also learnt to their surprise that cattle could make use of the lower successional species. 'Peach (or cow) vine and rhynchosia are highly nutritious. They may not be preferred forage plants, but they're palatable. The stock get stuck into devil's claw. Pumpkin vine, yellow vine and tarvine are edible. So you get some production from these species.'

Richard admits you need a strong heart. 'We have photos of rolypoly paddocks where you had to stand on top of the vehicle to see across the paddock – a few short



Regenerating pastures on the black soil plains in the first year after cropping are dominated by back rolypoly, volunteer sorghum, various vines, devil's claw, turnip and scattered tussocks of native millet. (Photo courtesy of Janet and Richard Doyle)



By year 2, legumes such as rhynchosia and blow-in grasses such as native millet dominate the oldfield succession on the black soil country. (Photo courtesy of Janet and Richard Doyle)

years later, it's turned to grass and there's not a rolypoly there. So it doesn't worry us so much anymore. Provided you are focused on the desirable perennials when they start to appear, and you look after them with grazing management and allow them to spread, it's OK.'

The Doyles have observed a similar successional sequence on their different types of country several times over the past 7 years. On black vertosols in the first year after cropping, the weedy pioneers are black rolypoly, volunteer plants from the last crop, paddy melon, devil's claw, peach vine, turnip and native millet. More grass comes in years 2–3, including annual grasses like barnyard grass. There are '... huge amounts of native legumes like glycines and rhynchosias, wall to wall', says Richard. 'By this time, things like cow vine disappear by themselves and the blow-in grasses have gone berserk. Any grass that can fly in does, and after 3 years the native millets are everywhere, providing great groundcover. We are seeing other good early colonising grasses like umbrella grass and thick patches of bluegrass.'

By year 3, curly Mitchell grass starts to appear and a little hoop Mitchell grass as well. Warrego summer grass has been slower to spread on newly colonised country. Richard observes, 'It's a preferred grazing species early in the season. Shotgrass is prime tucker, too. These are big-seeded grasses. We are very lucky to have them on the black country.'

A similar sequence of native pasture regeneration occurs on the alluvial grey clays on their river country. 'You go through three stages, the successional process being similar to the black soil plains: yellow vine, tarvine, peach vine and rolypoly are first. We got fantastic grazing out of the vines in the first year. These early successional species disappear fairly quickly as the early successional grasses start to appear. Curly windmill grass takes off as does tall windmill grass, in fact both chloris species. Queensland bluegrass is an early coloniser, particularly in better seasons. Saltbushes are early successional species. Mueller's saltbush likes to cover bare ground, and there is a lot of copper-burr briefly.'

'Very quickly you start to see later successional species. A lot of hoop Mitchell grass has come. We can distinctly remember our excitement seeing a hoop Mitchell grass,' says Richard. 'Now it's everywhere. Ditto for curly Mitchell grass. They are both rapid colonisers.



By year 3 on the black soil plains, native grassland dominated by blow-in species has regenerated with a scattering of large-seeded grass species such as hoop and curly Mitchell grass. (Photo courtesy of Janet and Richard Doyle)

In fact, the regeneration of native perennials has been very encouraging.'

'Trees like doolan [cooba] are popping up now in the river country pasture. We need to control their regeneration since we want to retain the option to pasture crop. It's a design question with woody regrowth about where to leave trees. We have tried leaving them along the fence line.'

Richard observes that perennality and diversity appear to be a natural consequence of what they are doing. He also views it as a breakthrough when he and Janet began to understand the importance of successional transitions, accepting them as inevitable, necessary and healthy. 'Don't try and kill all the early successional vines and rolypoly. If you bring the system back to ground zero each time and let the weeds cash out, something similar will take their place. The perennials just need time and maybe the annuals to get going. But the perennials do come ... and quickly.'

Richard and Janet have experimented several times with pasture cropping to try and improve ground-cover, soil organic carbon, provide winter feed, take pressure off the native pastures, and encourage winter

biological activity in the soil in years when the winter annual growth was subdued. ‘We haven’t had a lot of success planting exotics to speed the process up,’ observes Richard. They trialled forage oats, millet, silk sorghum and dry-sown grazing barley as winter feed, but the seasons were not kind.

One or two of the less productive paddocks with a long history of cropping were sown to introduced sown pastures, including bambatsi panic, green panic and floren bluegrass. However, the results were disappointing, with persistent low groundcover and pasture productivity and high lippia cover. A return to above-average seasons may kick-start these exotics, but at the same time, the Doyles are encouraged by the increasing population of natives through the paddocks.

On some of the older cropping country, Richard and Janet have experimented with short-term annual forages such as forage oats, forage sorghum, dual purpose wheats, and lablab and vetch for green manure. The difficulty in controlling weeds has been a constraint. While some conventional forage production will continue for the time being, Richard and Janet’s focus at Malgarai has swung to natural regeneration of perennials for the longer term.



Pasture cropping of barley in the third year of native pasture regeneration on grey alluvial clays. (Photo courtesy of Janet and Richard Doyle)

Sowing Mitchell grass at Walgett

Greg and Helen Weber own ‘Fairlands’, a 4000-ha dryland grazing and cropping property in 400-mm rainfall country at Walgett, north-west NSW. The country is open coolibah woodland on grey cracking clays, and is periodically flooded by the Namoi River, 7 km away. Being almost in the state’s arid Western Division and with heavy clay soils prone to extended drought and floods, the Webers experience their fair share of boom–bust cycles. Due both to prolonged droughts and floods and periodic cropping, Greg and Helen saw the need to re-establish native pasture in a more timely fashion than simply waiting around for nature to do it. One of the problems for dryland farmers and graziers in the lower Namoi catchment is that native pastures recovering from severe disturbance normally pass through a successional stage dominated by black rolypoly, which is a short-lived native chenopod bristling with spines and with little feed value. Although black rolypoly acts as a nurse plant and traps wind-blown native grass seed and protects seedlings, it can take years for pasture dominated by black rolypoly to shift back to native grass dominance if the seasons are unkind. Greg and Helen saw a short cut.



Sown subtropical grass pastures have underperformed on degraded black soils along Whalan Creek. (Photo courtesy of Janet and Richard Doyle)



Curly Mitchell grass in a dry spell (left) and flowering spikelet. (Photo left: Rhiannon Smith)

Curly Mitchell grass is one of Australia's best known arid zone pasture grasses, and is common on clay soils in the lower Namoi catchment where flooding does not occur. It is a moderately palatable, long-lived, perennial tussock, tolerant of grazing, and readily resprouts from the base in response to rain after drought, fire or heavy grazing.²⁸⁵ However, it dies if flooded and therefore does not normally occur on floodplains subject to frequent inundation. It is heavy-seeded and therefore does not readily 'blow back' into areas from where it has been lost, in contrast to many other native grass species. The heavy seeds and erect cereal-like seed heads of curly Mitchell grass gave Greg and Helen the idea that maybe they could treat it just like one of their wheat crops. Their success exceeded expectations.

Greg harvests seeding stands of curly Mitchell grass on the family property or harvests seed on neighbours' properties in summer and autumn after good rains. When soil moisture conditions are ready in a paddock destined for sowing, a small commercial seeder pulled behind a utility or tractor is used to dribble the seed out on to the soil surface and turned in using a light set of harrows behind the seeder. Crop fallows and stubble, open woodland and flogged grassland areas have all been treated in this way and returned to curly Mitchell



A sown paddock of curly Mitchell grass at Fairlands, with occasional plants of black rolypoly and native millet.

grass pasture with great success, bypassing the weedy rolypoly stage because the Mitchell perennial grass is highly competitive and establishes in high density. The resulting pastures can either be returned to grazing, like a normal native pasture paddock, or can be baled for Mitchell grass hay due to the purity of the sown stands.



Greg has sown curly Mitchell grass in coolibah woodland that lost the species after floods and prolonged inundation by seeding the interspaces between trees.

Helen and Greg have employed an alternative revegetation strategy using Mitchell grass hay as thatch. By mulching areas around the homestead with Mitchell grass hay, they have been able to return bare ground to grassland and reduce the dust burden around the house. Alternatively, feeding out the hay to cattle can reintroduce seed into paddocks lacking Mitchell grass, and make use of the cattle to disperse the seed throughout the paddock.

Helen and Greg's innovation has provided a commercial opportunity as well. They sell curly Mitchell grass seed and ship it all over Australia. Rather than the prospect of bare weedy paddocks as a result of climate change and more frequent drought in outback Australia, the Webers' innovation will help keep the inland floodplains grassed up should their innovation with the harvesting and sowing of Mitchell grass seed catch on.



The Seabrook Seeder™ and harrows used to sow curly Mitchell grass on grey cracking clays at Walgett, NSW.

Sustainable management of native forests

Native forest on farmland can yield an economic return as well as protecting native biodiversity values through the implementation of sustainable forest management. While attempts at sustainable management of native forests have a long history, these have often been focused on sustaining a timber harvest rather than sustaining broader forest ecosystem values. Terms such as high grading perhaps best describe these approaches. Sustainable forestry as we know it today is based on an understanding of the ecology of the forest and of the biodiversity values present, with harvesting aiming to mimic natural disturbance regimes and facilitate natural regeneration through careful tree extraction. Clear definition of management goals, especially in relation to biodiversity, and a willingness to implement innovative (and conservative) management approaches are also essential. Notwithstanding this, sustainable harvesting is a potential tool for private landowners with substantial areas of forest that also have important biodiversity values.

Native forest on private land can contribute to biodiversity conservation both through the habitat it

provides for resident species and through connectivity to and buffering of other areas of native forest (e.g. in adjacent reserves). The presence of old-growth features (e.g. large mature trees, dead standing trees, coarse woody debris, vertical and spatial heterogeneity) are important for sustaining biodiversity within a stand, while the presence of continuous forest cover helps enhance connectivity for many forest species.²⁸⁶ Management that aims to retain these features is likely to also facilitate biodiversity conservation.²⁸⁷

In mixed-species forests that are subject to small-scale disturbances such as the podocarp–broadleaved forests of New Zealand, single-tree harvesting that spreads harvesting across a range of size classes and species and that aims to leave a proportion of trees to die naturally, can result in the retention of many old-growth forest elements.²⁸⁸ The use of helicopters rather than ground-based machinery for timber extraction can further reduce site impacts. However, in forests that are subject to more extensive disturbances such as catastrophic windthrow or fire, harvesting is more difficult as single-tree methods are likely to alter forest composition or result in the failure of light demanding canopy trees to regenerate. In these forests, coupe harvesting is more appropriate, with trees harvested in groups and management implemented post-harvest to facilitate regeneration.

In New Zealand, management of native forests is closely regulated through the *Forests Act 1949*, which prescribes the species that can be harvested, the amount of timber that can be extracted, the spatial arrangement of harvesting (e.g. single tree vs coupe harvesting) and forest reserve requirements. Management plans are required, and auditing is undertaken by Ministry of Primary Industries staff. Forest owners also usually require local government consents, which frequently include further conditions relating to biodiversity management.

In Australia, regulations governing private native forestry (PNF) vary from state to state. In NSW, following changes in August 2007 to the *Native Vegetation Act 2003*, harvesting of timber for the purposes of PNF requires



Cutting up a felled rimu ready for helicopter extraction, Westland.

approval through a property vegetation plan (PVP) that ensures environmental outcomes are improved or maintained.²⁸⁹ A PNF PVP is a legally binding agreement between a landholder and the Office of Environment and Heritage. A PNF PVP consists of a satellite image or aerial photograph of the property, identifying the part subject to the PVP. The map identifies areas that cannot be logged, such as rainforest, old-growth forest, steep land ($>30^\circ$) and riparian exclusion zones. The PNF PVP also includes a declaration that the forests identified in the PVP will be managed according to the PNF Code of Practice, the detail of which varies in different parts of the state. In addition to the exclusions above, the Code either does not permit or restricts logging in some areas (e.g. rocky outcrops, endangered ecological communities), although these restrictions can be reviewed if they impact on a landholder's net harvestable area by $>10\%$. As in New Zealand, the NSW Code specifies a range of

requirements with which the landowner must comply, including harvestable species, the basal area and amount of canopy that must be retained, harvest restrictions and annual reporting requirements.

Logging inevitably changes forest structure and composition: a managed forest will never be the same as an unmanaged forest.²⁹⁰ Key changes may include: a reduction in the amount of coarse woody debris on the forest floor as tree trunks are removed, reduced soil turnover as trees are felled rather than allowed to blow over, long-term changes in forest composition and structure, and loss of mature and senescent trees which provide key habitats for much forest flora and fauna. Notwithstanding these concerns, a harvesting approach that ensures the harvesting cycle is sufficiently long to match the life cycle of the harvested trees, leaves a proportion of trees unharvested and that minimises impacts on the forest floor, is likely to result in a forest



A single tree harvest site after a rimu log was extracted by helicopter, Westland. The photo was taken standing on the stump looking towards where the tree crown fell.



Harvesting stringybark in a private native forest, NSW.

that retains many of the elements of an unmanaged forest. Where forests have been previously harvested, or where introduced species threaten biodiversity values, instigation of restoration management and weed and pest control as part of forest management may well enhance biodiversity values beyond those that would be present if no harvesting took place. Niche marketing of high-value sustainable forest timbers also provides the opportunity for a better economic return than traditional uses of native forest timbers, especially coupled with certification through a scheme such as the Forest Stewardship Council.

Mangatu forest on the east coast of New Zealand's North Island is a 15 000-ha partially cut-over indigenous forest owned by the local Maori iwi (tribe). The forest is currently riddled with goats and possums, while introduced predators threatened native fauna. Notwithstanding this, the forest still contains populations of several key threatened bird species including North Island brown kiwi, blue duck (whio), bush falcon, kaka (parrot) and kakariki (parakeet). Various forest trees including red beech, silver beech, tawa, hinau, pokaka, rimu and miro are harvested, with harvesting spread across a range of size classes and with no more than 60% of the annual merchantable tree growth harvested in any one year. Harvesting is restricted to no more than one tree per 10 ha, and trees are either harvested singly or in groups of no more than four trees and extracted by helicopter. To offset the impact of harvesting, the forest owners have set aside a substantial area of reserves (22% of the forest management area, representative of the full range of forest types present). They are implementing an active predator control program focusing initially on reducing goats to very low levels, and later possums



Kakariki, one of the bird species that benefit from predator control programs associated with the sustainable management of native New Zealand forests.

and mustelids (stoats, ferrets and weasels), restoring an area of pasture between Mangatu forest and adjacent public conservation land, and establishing a forest-wide biodiversity monitoring program. In addition, an endowment fund has been established to ensure that sufficient funds are available to undertake the biodiversity work in years where no income from harvesting is available.

Falcons and vineyards

The native New Zealand falcon, *karearea*, has declined steadily since human settlement as a result of habitat loss and predation by introduced animal pests, with perhaps only 4000–8000 birds remaining in the wild. The eastern South Island form of the falcon is classified as ‘Nationally Vulnerable’, the third highest category in the New Zealand classification of threatened birds. However, a recent initiative aimed at using falcons as ‘natural’ pest controllers in New Zealand’s premier Sauvignon Blanc producing region, Marlborough’s Wairau Plains, is promising to reverse this decline while also providing an important economic benefit to the wine industry.²⁹¹ Three introduced birds (starling, blackbird and song thrush) and one native bird (silveryeye) cause significant damage to grapes, even when physical and acoustic deterrents are used. Vineyards can suffer up to 23% grape damage due to both pecking and plucking of whole grapes, resulting in industry-wide losses in excess of \$70 million per year from bird damage.²⁹²

The New Zealand falcon is one of only three birds of prey remaining in New Zealand, and the only endemic species, the others being the Australasian

harrier (*kahu*) and the morepork (*ruru* or boobook owl) – other endemic birds of prey such as the giant Haast’s eagle, sea eagle and the laughing owl are now sadly extinct. The eastern falcon is confined to the dry forests, shrubland and grasslands of the eastern South Island. It feeds on small birds, rodents, rabbits and large insects, diving at speeds in excess of 200 km/hr in making a kill. The falcon nests in shallow scrapes on the ground, for example on a cliff ledge or under a rock overhang, making chicks vulnerable to predation by introduced rats and stoats.

The ‘New Zealand falcon conservation project’ is working with the Wairau Plains vineyards in establishing a resident breeding falcon population. Falcon chicks have been translocated from the surrounding hills and reared in the vineyards since 2005. Several of these birds have now paired up and are successfully breeding in the vineyards. The use of predator-proof artificial nests means that chick survival is high compared to the wild. Artificial food is supplied for part of the year, but as the grapes start to ripen in late February, the food supply is reduced so that the falcons start to



Bird pecking damage on Gewürtztraminer grapes. (Photo: Sara Kross)



Juvenile falcon in vineyard, Marlborough. (Photo: Sara Kross)



Wairau Plains vineyard where falcons are helping limit grape damage. (Photo: Hayden Oliver)

hunt more seriously, providing maximum predation pressure during the most vulnerable period of grape production. Early research results found that falcon presence significantly decreased the number of introduced European pest bird species hence reducing the incidence of grape removal. However, the number of native silvereyes that peck grapes causing fungal infection was not reduced, although the amount of pecking was.²⁹³ It is likely that falcons affect these pest birds both through direct predation and the threat of predation, which changes their behaviour. As a result of this, the presence of falcons has the potential to reduce grape damage by over 75%.

The project has not been without its challenges. Of the 15 chicks translocated in 2006–07, five were electrocuted, one was killed by a cat and one killed on a road. To avoid electrocution, birds are now being released as far from electricity poles as possible, while discussions have started with electricity suppliers on means to reduce this risk. There has also been a strong effort in raising the awareness of vineyard owners and others who live on the Wairau Plains to the potential benefits of falcons in reducing pest bird damage. Falcons do attack domestic animals, especially poultry and pigeons during

autumn and winter, with most of the negative reaction to the project coming from people who keep free-range chickens or pigeons. Falcons can also be aggressive birds especially when nesting, although this does not appear to have been an issue here. However, given these concerns, the project has worked hard to highlight the benefits of the program in order to gain broader acceptance.

This project has already brought a nationally threatened bird back into an area where it was locally extinct and in doing so has provided sustainable biological pest control, replacing less acceptable methods such as poisoning, shooting, trapping, netting and banging. In addition, the use of falcons for pest control means that vineyard owners no longer need to clear woody vegetation in order to remove cover for pest birds, enhancing the amount of woody habitat for biodiversity conservation. Finally, the return of falcons to the Wairau Plains has considerable potential for both marketing the wine from this area and as a focus for local tourism. Investigations are now underway on the potential of using falcons for pest control in other wine-growing areas (e.g. the Pinot Noir region of Central Otago) and for related industries such as market gardening and arable farming.



A painting of an azure kingfisher by Richard Weatherly. (Courtesy of Jenny and Richard Weatherly)

10

PROPERTY CASE STUDIES

The final set of case studies focuses on individual farms and the approach that farmers have taken to managing biodiversity on their properties. In some cases they have undertaken only one activity, but in other cases they have implemented a range of management initiatives that benefit biodiversity while still running their properties as profitable businesses. Some of the management described in these case studies might be best described as indirect, in that the management is directed primarily towards overall farm productivity, but in implementing these actions there are also very obvious biodiversity benefits. Other management initiatives are aimed at directly enhancing biodiversity.

As with the other case study sections, the case studies included here are by no means exhaustive in terms of the many different actions that farmers have taken for biodiversity, but are designed to provide real-life examples of what working farmers and their families are able to do within their farming operations (i.e. within the constraints of needing to run successful farm businesses). We see these case studies as flying the flag, so to speak, for just how well biodiversity management can be incorporated into farm management and the power of positive farmer-driven initiatives resulting in win-win outcomes for both biodiversity and farming.



Biodiverse farms can be extraordinarily beautiful.

Rangelands – Glenmore

Will and Emily Murray are the fourth generation of Murrys to farm Glenmore Station, a 19 200-ha iconic South Island high country property with high snow-clad mountains, long river valleys and extensive downlands running out to the shores of Lake Tekapo. Farming is based on grasslands, tall tussock at higher altitudes and short tussock lower down, with irrigated pastures on some of the flats. The climate is demanding with warm dry summers and cold winters, often with hard frosts and snowfalls. As a result, the growing season is short and the production potential limited. Farming is based primarily on fine wool from 9800 Merino ewes and hoggets, although some 400 cattle are also run and the property has a 400-head red deer herd. About 500 ha of flats are cultivated (and about half irrigated) and a little under 5000 ha of downlands and lower mountain slopes are aurally over-sown with cocksfoot

and white clover seed and fertilised with superphosphate, with some of this currently being converted into ryecorn and lucerne. The remainder of the property has not been developed, with natural barriers often taking the place of fences, and extensive areas of talus and rock. Glenmore has very high natural values including extensive tussock grasslands, rare ecosystems such as kettle-hole tarns (small lakes), remnants of the pre-human montane woody vegetation in fire-free refuges, and a number of nationally threatened plants and birds.

Will and Emily see farming Glenmore as being about managing the natural values as much as the economic potential, and they are committed to handing the property on to their children, Angus, Greta and Ben, in as good a condition as they received it. Biodiversity is integrated into farm management through a whole-property management plan.



Glenmore Station with cultivated flats behind woodlots and summer grazing in the background.

Their vision for Glenmore is:

The economic potential of Glenmore Station is being fully utilised while maintaining and, where appropriate, enhancing other values present (especially native biodiversity and recreation), in a manner that is resilient, dynamic and flexible.

In order to achieve this vision, they have identified seven outcomes they believe need to be achieved over the likely 30 years or more of their stewardship of Glenmore Station:

1. Glenmore Station is an economically viable farming unit
2. Glenmore Station provides for the family's needs
3. Farm management is a multifaceted and sustainable operation
4. Animal welfare issues are a central consideration in farm management
5. Significant natural values on Glenmore Station are being sustainably managed
6. Appropriate public use of Glenmore Station is facilitated
7. Management activities are monitored.

There are several facets to biodiversity management on Glenmore. Will's parents, Jim and Anne, established an open space covenant with the QEII National Trust over 995 ha of downlands in order to protect an internationally significant kettle-hole tarn system. These tarns formed as the Tekapo Glacier began to recede at the end of the last glaciation. Rather than retreating back up the valley, the ice melted *in situ* and the resultant ablation moraine contained numerous small hills and hollows (the kettle-holes). The tarns have formed in these and the turf around their margins is habitat for at least six nationally threatened plants, while nationally threatened birds such as the black stilt feed in the tarns. The covenant does, however, provide for light Merino grazing, as without grazing invasive exotic plants such as thistles will gradually outcompete the native species resulting in loss of the turf vegetation and the threatened plants that live there.

Wilding conifers are a major threat to both biodiversity and economic values on Glenmore. Some of



Will and Emily Murray, and their three children, Greta, Ben and Angus.



The nationally endangered black stilt, possibly the world's rarest wader, occurs on Glenmore Station.

the seed comes from early shelter plantings around farm huts while other seed comes from more distant sources. Will and Emily and their staff spend several days each year cutting wilding conifers across the property – a laborious and time-consuming job that requires them to cover large areas on foot to locate and remove the often isolated trees. If Will and Emily don't keep on top of these isolated wildings, these trees will quickly set their own seed and the whole farm will turn into a wilding forest

with no grazing potential, loss of the open grassland and wetland habitats essential for the threatened plants and animals that are present and with little timber value. More recently, Will has been systematically removing the planted trees around huts as removal of seed sources is the best long-term solution to the wilding conifer problem.²⁹⁴ However, it is not possible to remove seed sources from adjacent land so ongoing vigilance and control will continue to be part of farm management.

Another key component of biodiversity management at Glenmore is monitoring biodiversity condition. Will and Emily realise that they need to understand the interaction between their management actions and biodiversity, if they are to ensure that native plants and animals continue to flourish. They have been working with a broader biodiversity research program²⁹⁵ and now have 48 land-cover and 10 aquatic monitoring sites across the property. These are monitored every 3–5 years and the monitoring results are starting to build up a picture of how biodiversity values are changing through time. Land-cover monitoring is based on photo-points that Will and Emily can interpret themselves as well as more detailed floristic surveys, while aquatic monitoring involves water analysis and identification of stream invertebrates. Will and Emily see this as equally important in farm management as, for example, monitoring soil fertility or fleece weights, as biodiversity monitoring enables them to assess how their farm management inputs are affecting other values, such as tussock cover or stream health.

Even their irrigated flats can provide biodiversity benefits. Irrigation is undertaken using a flood-irrigation system where individual paddocks are flooded on a regular rotation to ensure that there is sufficient soil moisture for good grass growth during the summer. However, flooded paddocks also provide habitat for a number of native wading birds such as oystercatchers, variable stilts and the nationally threatened black stilt, as well as black swans, black-backed gulls and paradise shelducks.

Biodiversity management is a core part of farm management at Glenmore and is something that the Murrays are very committed to. Will and Emily view biodiversity as important both for its own sake and



Wilding conifer control is critical to remove a long-term threat to both economic and biodiversity values – felling and spraying have both been used here.



A monitoring site in snow tussock grassland on Glenmore Station used to track vegetation condition.

because of the benefits for the economic potential of the property, whether it be through bigger tussocks providing shelter for lambing ewes, clean water for drinking, or simply the ability to market the farm's products nationally and internationally based on their conservation work. However, biodiversity management can only occur if the property is economically viable: economic viability and biodiversity are inextricably linked. In the extensive rangelands of the South Island high country, it is not possible to have one without the other.

Rangelands – Woodgreen

Marie and Bob Purvis at Woodgreen Station, two hours drive north of Alice Springs in central Australia, have managed their beef cattle property since Bob took over from his father in 1960. Over the past 52 years, Marie and Bob have developed a management system that is a model of sustainable rangeland management.²⁹⁶ Features of the system include: (1) subdivision and spelling of country; (2) a stocking rate that is sustainable through all seasons and that initially improves and then maintains pastures and groundcover through boom and bust; (3) landscape restoration and revegetation of eroded country; and (4) occasional use of fire to manage woody encroachment on productive grazing country. Although formal biodiversity surveys have not been undertaken at Woodgreen, the improving landscape health of the property is supported by Bob's range condition monitoring system that he developed himself.

Woodgreen was originally settled to breed horses, so it was an advantage that there were only small areas of alluvial soils that grew horse poison. The fact that there

was no permanent water meant that Aboriginals did not reside there, avoiding the conflict that Bob's father had seen elsewhere. Over time, the best country came to be overstocked because of a misunderstanding of the carrying capacity. Indeed, land administrators at the time decreed a minimum stocking covenant that was 10 times above the station's carrying capacity even in its best condition. Bob emerged from the 1959–65 drought with 280 head of cattle and a debt equivalent to the value of the station. He had two options, 'walk off, or drag the place up by the bootstraps'.

The lack of highly productive country dictated that the industry practice of maintaining a large breeding herd and turning off marketable young cattle was not feasible. To meet regular repayments, Bob had to insulate himself against the seasonal and market fluctuations characteristic of pastoral Australia. Heavy, quality three-year-old bullocks were the answer. These animals fetched high prices and held condition in the dry, if run on nutritious pastures. Bob progressively



Quality Woodgreen bullocks. (Photo: Jim Purvis)

reduced his breeding cow herd from 1000 in the early 1970s to 420 in the 1980s and 350 in the 1990s. He bred his own bulls from his best cows and a small number of purchased bulls that met his genetic requirement. These station-bred sires were well adapted to the climate and pastures, produced high quality progeny that fetched top weight at market, and were docile and easy to muster, continuously improving the quality of the herd. Despite massive price and rainfall fluctuations, Bob's livestock strategy has ensured a modest stable income.

To escape the debt cycle, more high quality land was needed to produce marketable stock and become viable. The adjacent Waite River run came up for sale in 1971 and 470 km² of largely good country was purchased. Despite increased debt, the better country increased from 130 km² to 450 km². This provided the productive capacity to service debt and start to repay the principal.

Bob learnt through observation that as little as 5% of the pasture growth in poor mulga country is palatable. Removal of this palatable portion through overgrazing results in degradation, despite the fact that mulga country is generally presumed to be robust. He found that small numbers of breeding cows can live on the infertile mulga country with weaning, supplementation and clean water provided palatable forage is present. The limited amount of good country where potentially 90% of the forage is palatable is reserved for marketable stock only (steers, surplus heifers and cast-for-age cows).

When Bob took over Woodgreen, the western half was mainly spinifex sandplain, which was ignored as

it could not produce economic returns. Bob returned this country and much of the poorer mulga country on the west side of the property to the NT government more than 10 years ago. The area is now managed as a conservation park.

Bob used to manage adjoining paddocks in pairs, with cattle spending 6 months in each paddock. Nowadays, all cow herds use a three-paddock system and periodically each paddock is destocked totally for 12 months. This overcomes the vagaries of individual paddocks being locked into either unreliable summer or winter rains for recovery. It also allows flexibility to take advantage of fresh feed resulting from scattered storms in a dry year.

The strategy of reducing cattle numbers to match the carrying capacity of the land and keeping a large proportion of the station in reserve has increased the proportion of palatable species. Bob describes how he developed a simple test to determine land condition anywhere on Woodgreen:²⁹⁷ 'If the mulga country has more than seven species of edible grass or small perennial herbs visible when standing in any one area, it is in good order. If it has five species it is at its lower limit, and if it has three species or less it is degraded. If the best fattening country has 10 or more edible species visible from the one spot, it is in good order. At seven species it is at its lower limit, and three or less it is degraded. My experience is that when both of these usable areas are in good order, then other living things are active and healthy. Take birds for instance. We used to have very few birds here when the country



Grass growing right up to a trough at Woodgreen, demonstrating the sustainable stocking rate maintained by the Purvis family.



Brown quail live in the garden at Woodgreen homestead now the surrounding country has recovered. (Photo: Lydia Paton)

was degraded. We have lots and lots now, mainly the little fellows. Brown quail live in the garden, and from time to time we have a family of fairy-wrens around the house. We love having the birds around.'

'Sweet' grazing country on Woodgreen has many times the value of infertile mulga lands even when the preferred areas were degraded. Reclamation of preferred grazing lands was undertaken with three things in mind.²⁹⁸ It was apparent that time alone would not repair the damage since one paddock had been destocked for 25 years and nothing had improved. It was essential to retain rain water on the potentially productive landscapes rather than let it flow down 'gutters' (eroded shallow gullies) or into areas thickly infested with woody weeds. Where overgrazing had eliminated the palatable perennial grasses, it was essential to reintroduce forage plants. The result was the use of ponding banks and buffel grass.

Bob and Marie learned that it takes from 5 to 20 years to revegetate an eroded or scalded area, depending on seasons and soil fertility. Ponding banks succeed because they catch the runoff and sediment as close to where it is shed as practicable, forming new topsoil and holding the rainfall in place. The aim was to build 35 to 50 banks a year, varying from 100 to 300 m in length. There are in excess of 1000 banks today. All the bulldozer work is done by son Jim nowadays.

Bob reflects on the role of buffel grass at Woodgreen: 'In its degraded state nothing would grow on our better country, so we trialled approximately 60 different grasses and legumes. Only two varieties of buffel survived. Buffel grass produces a lot of organic litter, increasing the soil surface fertility sufficiently for desirable native plants to colonise and grow happily with the buffel. The trick is to ensure that the stocking rate is geared to the survival of the palatable natives. If the stocking rate is too high the desirable natives will be eliminated again. Buffel roots can penetrate 1.5 metres, so buffel grass is a good recycler of nutrients that none of the desirable native grasses can match.'

Although reclamation work through construction of ponding banks continues today, buffel grass has not been sown to initiate the revegetation process for many years. Marie and Bob's restoration of their country has been so successful that there is now sufficient density of desirable



A ponding bank on Woodgreen Station, with dense grass on the upslope (ponded) side of the bank and the borrow pit on the downslope side.



Buffel grass along the base of the upslope side (left) of a ponding bank in the early 1990s, and regeneration of native grasses and shrubs upslope of the bank.

native perennial grasses to colonise newly ponded areas. Palatable varieties of buffel grass still occur and are an asset where palatable native perennials remain scarce. For those people concerned about the weedy nature of buffel grass, Bob observes that 'buffel is held in check by the return of the native species, and grazing helps control it. In fact, introduced weeds in general are not a problem as there is always competition from desirable species.'²⁹⁹

The degradation on Woodgreen led to dense shrub encroachment in the watercourses and on some of the best open woodland country. Initially, fire was the only tool that could cope with this problem. Bob learnt about fire behaviour on cool days with gentle breezes. He subsequently progressed to lighting intense fires on 40°C days with a strong north-westerly, knowing how each fire would behave because of patchy or sparse fuel load beyond the area to be burnt.

Bob observes that it can require three fires to control woody encroachment. 'It is difficult to get the first fire to burn in a fertile watercourse or flood-out that has been taken over by dense scrub – acacias, cassias and eremophilas. The only grass to carry a fire will be annuals that have grown after a very big rain, and this window of opportunity is rare – hence the requirement for a hot day and strong wind. Perennial grass growth is prevented by the woody encroachment because nutrients are locked up in the scrub and the woody plants take all the moisture. The second fire also needs to be after a big rain, but the

fire will carry more easily because some perennials will have appeared after the release of nutrients as a result of the first fire. By the time of the third fire, there will be lots of perennial grasses and in time they will become wall-to-wall with scattered big eucalypts. This process may take 20 years for the three fires. The trick is to never graze the perennial grasses out so that there is always some organic litter breaking down. If managed carefully, the perennial grasses inhibit scrub regrowth.'

'The difficulty with fire is to know how to achieve the least damage for the best result. If we didn't burn, Woodgreen would become a dense wasteland of scrub. We have learned that frequent cool fires are a disaster for they burn the grass and leave the scrub. Hot fires, on the other hand, burn some valuable trees. You may lose some trees with hollows, but fires also make new hollows to suit a range of nesting birds, from pardalotes [small insectivorous birds] to Major Mitchells [pink cockatoos] ... The desirable frequency of fire may be every 15 to 50 years.'



Native grass regeneration at Woodgreen. (Photo: Jim Purvis)



Dense woody plant regeneration in need of a fire at Woodgreen. (Photo: Jim Purvis)

Bob and Marie have fostered a love and concern for the land in their three children who all hope to see Australian agriculture managed sustainably in the near future. Jim and Ilara help work toward this on Woodgreen while Joe is working to buy his own property one day.

After more than five decades, the Purvises reflect on their stewardship of Woodgreen and the likely benefits for biodiversity. They paid off the last of the debt almost 30 years ago. They have been able to weather droughts, floods and poor prices and educate their family of three. By restoring the palatable native perennial grasses through sustainable grazing management and reclamation of country, biodiversity has benefited. After 50 years of hard-earned experience and outstanding success, the Purvis's message is 'Nurture the land, and if you want sustainability you must have biodiversity!'



A stand of mulga after a prescribed fire at Woodgreen, showing strong perennial grass regeneration. (Photo: Jim Purvis)

Native pastures – Lana

Karen and Tim Wright's 3350-ha property, Lana, on the New England Tablelands in northern NSW is an outstanding example of 'holistic management', a livestock business philosophy originating with Rhodesian rancher Allan Savory in the 1970s.³⁰⁰ Karen and Tim liken their fine wool and beef cattle business to farming with nature, and Lana really is rather like a big nature reserve. Native grass pastures and grassy woodlands swathe the flats and undulating slopes, punctuated by heavily timbered rocky hills and drained by well-wooded, vegetated streams. Native vegetation dominates the farmscape, and the country looks much like it would have appeared 180 years ago, when European squatters first arrived. Six declining woodland bird species call Lana home, as do platypus and koalas³⁰¹ and a wide range of native plants, including grazing-sensitive herbs.³⁰²

It wasn't always like this. Karen and Tim took over management of Lana from Tim's father, Peter A. Wright, in 1980 and ran smack into the 1980–82 drought.



Karen and Tim Wright. (Photo: Karen Zirkler)

At that time, the property ran about 7000 DSE with a mix of British breed cattle and Merino sheep. For the first 10 years or so, Karen and Tim continued the pasture improvement and forage cropping begun by Tim's father. The whole property was aerially supered and seeded from about 1960, and about 20% of the property was cleared or thinned and sown (ploughed or drilled) to pasture over 25 years to 1990.³⁰³ 'We sowed fodder crops of oats under-sown with vetch or a cocktail of pasture species including sub and white clover, fescue, phalaris, ryegrass and red clover,' Tim recalled. 'Using pasture improvement like this, we lifted our stock numbers from 7000 DSE in 1980 to 20 000 DSE in 1991.'

The problem was that on Lana's infertile coarse granite soils, this form of management barely broke even over 5 years after improving a paddock, and some things went backwards. 'After the 1981 and 1994 droughts, the lowest yielding paddocks were the sown paddocks, and the land suffered,' recalls Tim. Unpalatable species such as wiregrass flourished in the uncultivated country, and pasture weeds like pinrush invaded the sown country. The sown country reverted to native species, which, in retrospect, was a blessing.

By 1990, Karen and Tim decided some things had to change: (1) costs of production, especially labour, had to come down, and (2) grazing management needed a



The restless flycatcher is one of several declining woodland bird species found at Lana. (Photo: Lynn Pedler)



Comparison of set-stocked (left) and planned cell-grazed (right) pasture at Lana in March 1998. (Photos: Christine Jones)

radical rethink, partly to improve pasture composition and productivity and partly to use the livestock as the farm machinery for slashing, fertilising, sowing pasture, and so on. After attending Grazing for Profit and Holistic Management courses starting in 1990, Karen and Tim experimented with cell grazing between 1991 and 1993 and then moved to planned grazing in 1995.

Planned grazing based on holistic management guidelines involves intensive grazing with a high stock density for short graze periods, followed by long rest periods. In order to accommodate planned grazing, Karen and Tim subdivided Lana into 240 paddocks (about 10–25 ha each) in six different farmlets. Paddocks need about the same effective grazing area to work. Each paddock gets an average of eight days grazing per year, or two days per season, by a mob of 3000 DSE, meaning that 95% of the property is rested and recovering at any one time. In terms of stocking rate (4.5 DSE/ha in winter, 6.0 DSE/ha in summer). Tim says, ‘... we are well understocked most of the time. We like that buffer.’

Planned grazing is flexible. Cattle are usually run a couple of days ahead of the sheep because cattle open up the pasture for sheep and reduce the parasitic worm burden, while sheep take feed away from the cattle if they are together. However, cattle can be run with the sheep to stop the cattle getting too fat and reduce the risk of bloat. Alternatively, a split-leader system with a small mob half way around the farmlet ahead of the main mob can be used when the pasture is actively growing, to fatten stock or to initiate cycling in young

maiden stock. A paddock can be missed to allow valuable pasture to seed: ‘... you don’t need to use machinery to sow a pasture.’ Once, when the eucalypt regrowth was thickening up, Tim left the stock in a paddock for an extra half day to browse the suckers and thin the saplings. This worked a treat but Tim tries to avoid doing this, as the stock overgraze the pasture if they are in a paddock for too long. Planned grazing has allowed stock numbers to increase on Lana and Kasamanca (the Wrights’ 780-ha property 50 km away) to between 18 000 and 24 000 DSE since 1995. Karen and Tim have achieved this with one-third the fertiliser inputs of the 1980s, and without fodder conservation, buying or growing feed or hand feeding for nearly 20 years.

The change to planned grazing necessarily involved new fencing and stock waters. Permanent suspension fencing was the answer at a cost of only \$1100 per kilometre including labour. A tank system and troughs were introduced to complement the dams and streams. ‘The cleaner the water, the better. There’s proof from Nebraska feedlot research that cattle do better on cleaner water’, says Tim. Troughs are also good for the leader–follower system when cattle foul the dam water. The refencing and water program was completed over a six-year period, and was funded by reducing other costs, such as fertiliser and hay, and abandoning pasture sowing and renovation. The cost of fencing and water per hectare was about the same as a 125 kg/ha of superphosphate, with a much better return.

Karen and Tim are motivated by their holistic goal. Karen sums it up: 'We aim to develop and maintain our property as a pleasing, ecologically balanced environment. We also aim for a chemical-free product. By doing this we believe our wool and meat production enterprises will be healthier and more cost efficient. In turn, we believe this will lead to healthier profits for the future, as well as improving human health. We endeavour to expand the horizons and the opportunities for both ourselves and the community.' So how are they doing?

Work load

Karen and Tim are often asked if their form of management is a lot of work, tying them to the farm. Tim says, 'All we are doing is being a shepherd – doing what the stock want to do – opening and shutting gates for them. All the ewes and cows are trained, all were born on the place, and they know exactly what's going on. Lambing is another issue. Lambs might drop during a three-week period, so I open up three paddocks at a time and let them drift to reduce mismothering ... When we used to go away, we ensured there was someone to do the moves. However, in the past year and a half, our son Locke has come on deck full time so one or other of us is always around.'

Finances

Tim does his own wool classing and has seen the quality of the whole Lana wool clip improve with planned grazing, largely as a result of the reduction in wiregrass and vegetable matter in the wool, and a consequent decline in the ratio of skirtings to main lines and increased value of broken lines. While wool income has increased, costs of production have decreased with the main inputs now being fencing and general maintenance. As Tim says, 'We are not drenching as much, we are not sowing pastures or ploughing anymore, and we're not spraying weeds as much. We've kept the chisel plough for bushfires only, and the animals are our farming tools.'

The land

According to Tim, 'In 2002, we had 15.6 inches [398 mm] of rain, the lowest rainfall on record. 1902 was the next lowest rainfall. By dropping stock numbers by just eight per cent, we were able to carry the remainder right through the drought without feeding hay or grain, and the land was in good shape at the end of it. There was more groundcover in the old sown paddocks than there was after sowing them. The sheep camps used to be pinrush and thistle. Now the grasses beat the weeds.'



Cattle at Lana (left), one paddock ahead of the sheep flock, as part of the leader–follower variant of planned grazing. The dead red gum in the left of the image was killed by heavy box mistletoe infestation. Tim pollards trees heavily infected with box mistletoe to save them (right).

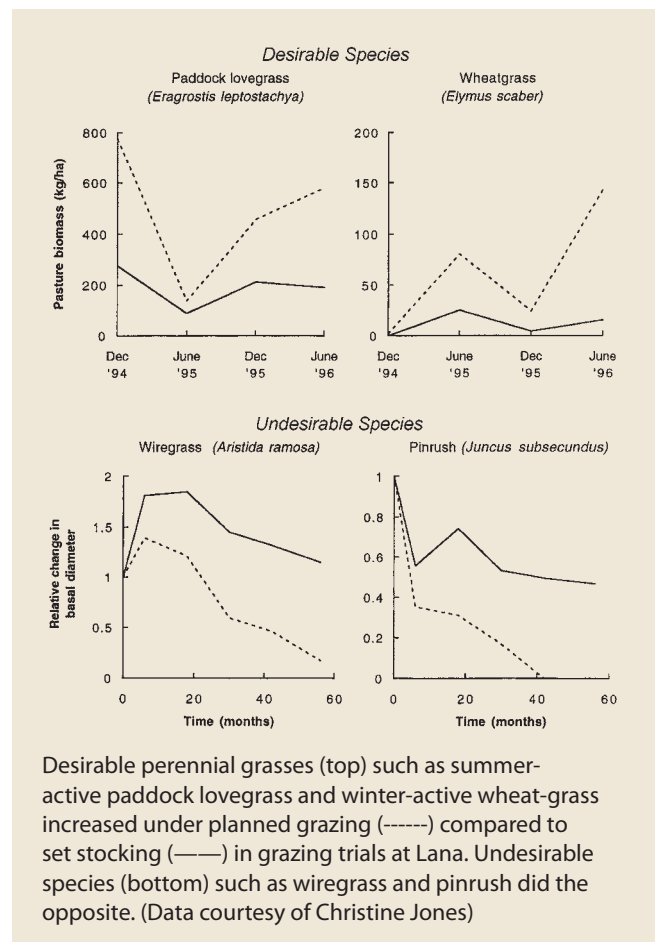
Drs Christine Jones and Judi Earl from the University of New England monitored the cell grazing trial in the early 1990s and documented a shift in pasture composition from undesirable to desirable species. 'During the study period, more perennials appeared including cool-season perennials than we had ever seen before. These carried the stock through the last drought,' says Tim. The biggest winner from the more productive, nutritious winter feed has been the cattle breeding enterprise. 'Sheep do well on short winter feed anyway. But cattle have to have good feed. Calving has probably increased ten per cent over the past 15 years due to the higher protein levels in the winter pastures and the better animal nutrition. All we do is provide minerals.'

Tim used to put out organic mineral blocks including urea for livestock, but he now imports 'Himalayan salt', a naturally occurring deposit of 88 different minerals from Pakistan, and puts out 10-kg 'salt lumps' in a rubber tyre in each paddock year round. Himalayan salt was used in Roman times as a natural livestock supplement, and Tim remembers coming across its use in South Africa for the first time: 'I couldn't get over the health of the stock. It's changed the grazing behaviour of the animals on Lana. The stock don't walk as far or graze as much as they used to in search of nutrients. They leave more feed in the paddock, which is good for the land. The cost works out at about 10 to 12 cents per DSE per year.'

Biodiversity

A healthy natural resource base and the native vegetation across Lana are important to Karen and Tim. 'We manage our biodiversity because it gives us a better balance – more is good,' says Karen. 'There are lots of indicators,' adds Tim. 'Our groundcover has improved. By working with soil biota and laying down litter, we are building soil through the composting effect, with increasing numbers of dung beetles, earthworms, mycorrhizal fungi and other microbes ... The increase in abundance and diversity of cool-season perennial grasses has given us more even feed production through the year. Clean water in rivers and dams is valuable for stock, and we have a diversity of birds for pest control.'

In addition to allowing the more palatable native grasses to dominate, planned grazing is helping some of the grazing-sensitive wildflowers turn up in Lana



pastures again. In late spring–early summer, one can find patches of scaly buttons (daisies), chocolate lilies, bulbine lilies, buttercups, native sarsaparilla and orchids in the small planned-grazed paddocks, not just in the lightly stocked hills. One rarely sees these plants on other farms in the region. The bird life is interesting too, with declining woodland birds like the brown tree creeper, jacky winter, speckled warbler, dusky woodswallow, restless flycatcher and rufous whistler all present.³⁰⁴ Lana therefore contributes more than most to conserving threatened plants and animals that are in danger of extinction in the agricultural regions of NSW.

Tim explains that one-third of Lana is dense timber and forested hills. 'Trees are important for stock shade and shelter. The shade is very important to reduce stress in summer, and the mild temperature beneath trees in winter keeps the grass green. Some of our best winter-active grasses like microlaena [weeping rice-grass] occur in the timbered areas ... Trees are an integral part of the ecosystem. The insect and bird life that lives in wooded areas affects everything, including pest control.'

Karen and Tim are interested in developing wooded corridors right across Lana. ‘Corridors are primarily important to us for shelter. They also increase the value of the land and help the wildlife move to all parts of the property,’ they observe. Regrowth is coming up in many places and is being used to link the watercourses and timbered hills with corridors of young trees. Lack of forest and woodland regeneration on farms is a major conservation concern elsewhere in southern Australia. ‘We have a lot more trees than when we started ... we don’t have to plant trees or build fences to protect plantings and remnants. We are just doing it with planned grazing,’ says Tim.

Planned grazing has had a positive effect on the vegetation in riparian areas fringing watercourses and dams on Lana. ‘The important thing is the rest that the riparian zone gets most of the time. Even though we run high stock densities, the planned grazing is helping our riparian zones recover, allowing vegetation to grow, erosion to heal and water quality to improve,’ Karen explains.

Karen and Tim have maintained Lana’s ‘wildlife refuge’ status. ‘Both our creeks have platypus ... We also have abundant birdlife, some koalas in the mountain gums, and wallabies up in the hills,’ says Tim. Rabbits are by far the biggest pest problem. ‘We don’t touch any timber in the hills, but we have to destroy some of the harbour [large logs under which rabbits burrow] out in the open. Otherwise, we leave the dead timber where it falls as habitat. I rip, burn, fumigate and shoot as often as I can but it’s an ongoing problem because of the nature of the country.’ In addition to rabbits, professional shooters control foxes and feral cats and keep the kangaroo and wallaroo numbers in check.

The triple bottom line

Through holistic management and planned grazing, Karen and Tim are achieving economic, social and environmental success. They have raised their four children who are now all independent, and made more time for family, friends and community service. Their business profitability has improved, and they are



Bulbine lily (left) and native sarsaparilla – two of several grazing-sensitive herbs in Lana pastures.



Planned grazing and conservative stocking rates at Lana mean that watercourses are well vegetated and eucalypts regenerate even in preferentially grazed areas.

working with nature to enhance their farm ecosystem's productivity and biodiversity, and improving the natural resource base. Karen and Tim are adamant that it all comes back to education, and learning how to make sound decisions within a holistic framework in order to achieve their family, business and environmental goals. They are modest about their success but keen to share



Tim Wright discussing carbon farming and holistic management with Professor Ross Garnaut AO (left) and the Hon Tony Windsor MP (centre) at a Lana field day in 2011. (Photo: Gemma Wright)

their experiences with others. Many hundreds of people from all parts of the world have visited Lana to learn about planned grazing, holistic management and farming with nature, and the flow-on effect to others extends to many thousands. If visitors and the people they tell are able to capture just a little of the Lana magic, both agriculture and the environment will be the winners.



Regeneration of Blakely's red gum in native pastures under planned (short-duration, long-rest) grazing.



Native pasture – Willydah

Bruce and Roz Maynard own Willydah, the 1500-ha family farm near Narromine in the Central West of NSW, where Bruce developed no-kill cropping (see p. 140). Bruce is a free spirit when it comes to farming, unconstrained by conventional thinking and behaviours, continually challenging assumptions, carefully observing the outcome of his numerous innovations, passionate about sharing ideas with others, and dedicated to encouraging farmers to think outside the square.

Willydah is flat to gently sloping with occasional flood ways and billabongs and a mixture of soil types from hard setting red earths to grey cracking clays. The original vegetation was grassland dominated by yanganbil (a tall *austrostipa* somewhat similar to plains grass), weeping myall tall shrubland³⁰⁵ and woodlands of yellow box,



Bruce, Roz and their three children (from left), Hannah, Ella and Liam. (Photo courtesy of Bruce and Roz Maynard)

western grey box, silver-leaved ironbark, and poplar box–cypress pine with an understorey of wilga, hopbush and Deane's wattle.³⁰⁶

The Maynard family had managed Willydah as a mixed farm (wheat, sheep, pigs, beef) for three generations when Bruce and Roz took over in the late 1980s. Times were tough due to a run of poor seasons and astronomical interest rates, and they found themselves in crisis management mode, responding to one emergency after another. The Maynards did a lot of soul searching about whether to stay and, if they did, what to change. Just about everything, as it turns out.

Bruce and Roz focused on the goal of returning the farm to as close to its natural state and functioning as possible, while still generating an economic return.³⁰⁷ Long-term sustainability and land stewardship were their guiding vision. Unlike most of the surrounding farms that were moving towards cropping (cereals and oilseeds), Bruce and Roz abandoned conventional farming and developed the grazing side of their business.

Twenty years on, when asked what this has meant for the farm, Bruce says '... our place looks vastly different in that our paddocks now are becoming more and more complex grasslands with trees and shrubs regenerating in them of their own accord. So the place is moving back towards an open woodland and shrubland that it would have been in its natural state. We try and make our business as simple as possible but the nature on our property as complex as possible. Whereas there's every societal pressure on all landholders to do just the opposite ... If you like, our aim is to increase the scale of our business and production, including biodiversity, without intensification. So, for instance, we are now helping offset our carbon emissions by moving to solar power on the farm and we have purchased an electric farm runabout.'

In order to assist the farm revert to nature, Bruce and Roz have widened the crown road reserves across the property by fencing out from them. They keep the woodland vegetation in the road reserves ungrazed to act as a seed source for the adjacent paddocks and to provide



An ungrazed crown road reserve of mature cypress pine and poplar box trees (right) at Willydah, showing the regeneration of these species in the formerly cultivated country within the fenced corridor on the left. However, regeneration does not occur in the never-cultivated soil adjacent to the mature trees.

300 ha of wildlife corridors surrounding and across the whole farm. Their road reserve network joins on to public road reserves as well, enhancing the connectivity.

The native trees have responded accordingly by starting to regenerate in the ungrazed pasture alongside. The patterns in tree regeneration are intriguing. In the formerly ploughed soils well away from the mature timber, box trees, cypress pine and wattles are freely regenerating. Closer to the native timber in the uncultivated strips, a different guild of trees is recruiting, led by western rosewood, wilga and kurrajong. The native grasses also signal the cultivation history of paddocks. Redgrass-dominated pastures are an indicator of previously cropped country, whereas never cultivated paddocks are more diverse and dominated by windmill grass, tall and curly windmill grass, wallaby grass, cotton panic and a range of forbs.

But allowing things to go back to nature hasn't meant a hands-off approach to farm management. 'There's a little bit of that,' says Bruce, 'but like all landscapes in Australia, they've been managed one way or another for

47 000 years, and ... there's no going back to a pristine state ... whether it be a national park or privately owned. So we have to manage the resource as best we can. We're all going to make mistakes as we move forward, but if our aim is just to continue to add diversity into the situation, then that's actually adding to our long-term wealth.'

True to their goal, Bruce and Roz have developed and implemented more than a dozen management innovations since 1990. The integration of all these approaches on the one farm sets Willydah apart as a truly remarkable operation. The Maynards started with saltbush block plantings in 1990 (see p. 148), followed by a whole farm plan in 1991; then time-control grazing (1994), access laneways (1995), no-kill cropping (1996, see p. 140), holistic resource management (1997), alley farming (1998), stress-free stockmanship (2000), 'whybother' tree plantings (2001), tree direct seeding (2001), advance tree seeding (2002), agroforestry tree plantings (2002), target saltbush plantings (2004), spiral saltbush plantings (2005), carbon tree plantings (2007) and multi-species grazing (2008).³⁰⁸

Alley farming involves parallel rows of old man saltbush separated by laneways of pasture. Target and spiral saltbush plantings are modifications of saltbush alley farming, except that the saltbush rows are arranged in concentric circles (like a target) or in spirals (to allow cropping machinery to work the alleys). These designs mean that livestock and pasture are sheltered no matter what direction the wind blows.

Whybother tree planting is a low-cost approach to establishing trees that does away with ground preparation. Home-grown tubestock are planted using a Hamilton hand planter after pasture biomass has been reduced by grazing and when soil moisture is high. Tree mortality is often greater than with a conventionally prepared planting bed and weed control, but the cost per established tree is much less. Advance tree seeding is direct seeding using a no-kill approach: a home-made tree seeder featuring coulter discs to minimise pasture disturbance is towed behind a motor or quad bike to sow the tree seed immediately after a grazing event and when soil moisture levels are high. Carbon tree plantings are several rows of blue mallee planted by CO2 Australia Ltd in every paddock, under lease for carbon sequestration.

Multi-species grazing involves grazing sheep and cattle together in ‘fherds’ to maximise meat production per hectare. Livestock on Willydah are not just the means of making money, they are the tools to create more diversity. According to Bruce, ‘... we use predominantly cattle ... to make the pastures more and

more complex with more and more native species. We don’t rely much on any of the introduced species at all such as lucerne or other pasture species ...’³⁰⁹

Willydah paddocks can contain up to 120 pasture species, including weeds. Bruce’s attitude to weeds might raise eyebrows, as he is relaxed about having as many weed species on the property as want to come. Being a practitioner of ‘stress-free stockmanship’ and having worked with Utah livestock nutrition expert Dr Fred Provenza, Bruce believes in providing livestock with a diverse forage base to achieve optimum nutrition. According to Bruce, stress-free livestock are able to metabolise plant chemicals that are toxic under more stressful conditions. Stress-free animals are therefore able to eat a wide range of plants, allowing them to choose the diet they need and to self-medicate. Thus, at Willydah, pampered livestock maintain plant diversity by eating a little of everything, including weeds, contributing to nutritional diversity and healthy livestock returns while keeping all the plants in balance. Through stress-free stock handling, Bruce has taught Willydah livestock to eat cypress pine saplings, saffron thistle, blue heliotrope and a range of other weeds that livestock generally avoid.

Many of the innovations at Willydah are about creating ecological boundaries and edge effects – boundaries between shrubs and grasses, and trees and pastures. Bruce believes that biological activity is maximised in the ecotones between vegetation types, reducing the reliance



The no-kill tree seeder was developed at Willydah to facilitate direct seeding of trees and shrubs when soil moisture conditions are optimal. (Photo courtesy of Bruce and Roz Maynard)



Bruce is generating a Willydah flock of meat sheep based on five breeds (Damara, Dorper, Van Rooy, Wiltipoll and Wiltshire Horn) of easy-care sheep suited to central western NSW. His medium-term goal is to run a flock of 5000 ewes for a store lamb enterprise.



Diverse winter pasture at Willydah, showing 100% groundcover and a mix of life forms including annual naturalised legumes (medics), winter-active speargrass and dormant, summer-active lovegrass.



Saffron thistles that have been defoliated and decapitated by stress-free Willydah livestock, despite the abundance of forage. (Photo courtesy of Bruce and Roz Maynard)

on artificial inputs to drive primary productivity, while maximising biodiversity for biodiversity's sake.

Fauna have benefited from the changes at Willydah. Grey-crowned babbblers, listed as vulnerable in NSW, relish the expanding woodland corridors across the farm. Bruce says 'Skinks have appeared and are dirt common here but not on other farms. There are lots of young dragon lizards; I can't remember seeing baby dragons when I was growing up. There is a lot of echidna and termite activity, lots of raptors, and quantities of small birds are back. Eastern rosellas have moved in over the last five years; red-rumped parrots and blue-winged parrots are common. Superb parrots come through twice a year. I saw the largest number of superb I have ever

seen in a paddock just the other day, and a government ecologist counted the largest number of superb I ever recorded in a 250-acre native pasture paddock here.'

The Maynards want to share what they have learned with others. With Col Seis, of pasture cropping fame (p. 138), and Angus Maurice, Bruce runs two-day short courses for farmers all over Australia, in which a lot of challenging concepts are brought together in a short time. While Bruce acknowledges that his conventional farming neighbours might want to reserve judgement about Willydah's 'messy' paddocks and unconventional approaches, '... the biggest change in adoption comes from people a bit further away from us. But we're starting to see a lot of progress, yes.'³¹⁰ Long may it continue!



The eastern subspecies of the grey-crowned babbler (threatened in NSW, left) and red-rumped parrots are common at Willydah. (Photos: Lydia Paton and Lynn Pedler)

Native/sown pasture – Melrose

One of the challenges in farming New Zealand hill country is striking a balance between the desire of the land to return to woody vegetation, and eventually native forest, and maintaining sufficient pasture growth for good livestock grazing – too much woody vegetation means a loss in economic productivity while too little woody vegetation can lead to soil erosion and lack of shelter for livestock and grass growth, and a loss of native biodiversity. Dugald and Mandy Rutherford have been tackling this issue with considerable success on their eastern South Island hill country property, and were recently rewarded for their efforts by being recognised as a Supreme Winner of the Ballance Farm Environment Awards.

Farm management at Melrose (3460 ha) is focused on diversity and farming within the constraints of the land. Since taking over Melrose from Dugald's father in 1974, they have purchased two smaller properties to complement their home property – The Haystacks (332 ha) 6 km to the west provides good lambing blocks and wintering country, while Woodford (126 ha) 11 km to the east is used for finishing stock and growing supplementary feed. Although Woodford has now been sold, Dugald and Mandy have recently acquired Double Tops (3700 ha), located adjacent to Melrose, in a 50:50

purchase/lease arrangement. Double Tops includes 300 ha of cultivated paddocks, which allows for the growing of winter feed and finishing stock. Because of their lower altitude, both The Haystacks and Double Tops are used for wintering stock. Melrose itself, which ranges from 460–1300 m elevation, includes a 110-head deer unit, a 200-ha trophy deer hunting block, lambing and calving blocks on the lower country, and extensive higher altitude areas for dry stock and wether grazing, and for autumn grazing of ewes and cows. Complementing these traditional farming operations, the Rutherfords also have some 200 ha in forestry (mainly radiata pine and Douglas fir). Farm income is diverse and includes sheep sales, wool (fine Corriedale and superfine Merino), deer sales, beef sales, velvet and forestry. Forestry plantings have been undertaken to provide for succession planning, allowing the farm to be passed on to the next generation of Rutherfords without unduly burdening them, and to provide income to non-farming family members in perpetuity.

Farming at Melrose is very much dependent on the vagaries of the weather, especially summer drought and winter snow. Ten bad drought years and two heavy snowfalls have occurred during the last 30 years. Dugald and Mandy do not believe that turning the property into



Dugald and Mandy Rutherford. (Photo: Nicola Hunt)



Melrose with a diverse mix of grasslands, native shrublands and forest, and planted woodlots. (Photo: Nicola Hunt)



Kea, a species that has benefited from predator control (left) and the nationally threatened tree daisy (right) on Melrose.

some form of high altitude 'dairy pasture' through intensive fertiliser application is sustainable, and instead they try to work with what nature provides them targeting fertiliser to the better soils and carefully matching pasture species to soil types. Forestry has also provided a good way to tap into water in the deep subsoils, with tree growth rates little affected during years of agricultural drought.

As a result of their management, Melrose still sustains a substantial amount of native biodiversity, notwithstanding the impacts of earlier Polynesian and European fires. The property includes numerous beech forest and shrubland remnants, wetlands, rock bluffs and talus slopes, and red tussock grasslands, while the dominant vegetation cover over most of the property is native tussock and scrub. A large number of native plants have been recorded including the nationally threatened tree daisy, *Olearia frimbriata*. Many native birds are also present including common species such as paradise shelduck and the Australasian harrier, as well as less common species such as rifleman (NZ wren) and kea (a mountain parrot). Of particular note is the successful fledging of young kea from two nests – kea have declined across much of the South Island

because of pressure from introduced predators and are particularly uncommon this far east of the main mountain ranges.

Management of native biodiversity includes fencing off of key high-value areas (e.g. forest remnants and wetlands), weed and predator control, and conservative grazing regimes that enable the native plants and animals to persist while still providing an economic return from the land. The Rutherfords are currently trialling predator-proof nesting boxes for the rifleman that occurs in some of their forest remnants, which they hope will lead to an increase in the abundance of this iconic beech forest species.

One of the biggest challenges for farming Melrose centres on the management of matagouri (a spiny native shrub) that occurs widely across the property. This species responds well to fertiliser (especially phosphorus) and represents the first step in a succession back to beech forest – the original vegetation across most of the property. Matagouri provides good natural shelter for stock, especially during lambing, as well as for pasture and the soil, but too much matagouri limits productivity. Traditional management of this shrub



Dugald Rutherford explaining farm management issues to university students during a field trip to Melrose.

involves either burning or herbicide, but neither of these are very selective and can harm other biodiversity while also removing all of the natural shelter. Dugald jokes that the ‘ideal spray would be one that removed every second bush!’ But in the absence of such a spray, matagouri control is selective with spray only being used on areas with good soils and on sheltered slopes that are not used for lambing.

One of the key factors that has allowed Dugald and Mandy to integrate conservation management into their farming operation so well has been both their diversified farming operation and having a good balance of land. The latter is particularly important as it allows them to accommodate adverse weather events without having to push land too hard or having to drop stock numbers to uneconomic levels. Owning the additional properties adjacent to Melrose helps improve the overall balance of their farming operation, which in turn helps sustain native biodiversity.



Matagouri shrubland providing shelter for farmed red deer. (Photo: Nicola Hunt)

Sown pasture – Balcarres

Pam and Ian Richardson, together with son Andrew and partner Jo, farm a 710-ha hill country sheep and beef property, Balcarres, in Holmes Bay, Banks Peninsula. Extending from near sea level to 621 m altitude, the property has a good mix of different aspects and slopes, which together with reliable rainfall (900–1200 mm) and equable temperatures makes for year-round grass growth. The property runs some 3400 Romney sheep and 260 Hereford and Hereford cross cattle (cows and steers), breeding its own replacements, and is generally capable of fattening a good proportion of sale stock with some sheep sold as breeding stock. A small part of the property is cultivated, but the majority is permanent pasture with ryegrass, crested dogstail, cocksfoot and white clover dominating.

Although the peninsula was once richly clothed in dense mixed podocarp–angiosperm forest, 700 years of human settlement saw this reduced to less than 1% of its original extent by the early 20th century.³¹¹ However, the benign climate has seen the forest quietly regenerating, especially where grazing is light. Balcarres is typical of this, with the property now having a strong natural character with some remnant old-growth forest trees, substantial areas of regenerating forest and shrubland dominated by native species such as kanuka, mahoe,

narrow-leaved lacebark, kowhai and coprosmas, and a range of native birds. Recent surveys of the property have identified the presence of 15 sites of ecological significance, and two plant species ranked as ‘At Risk’ in the national classification of threatened and uncommon plants:³¹² fragrant tree daisy and fierce lancewood.

The Richardson family vision for the property is:

A farming operation working with a balanced, diversified landscape where native ecosystems continue to flourish, special attributes of the property are protected and enhanced, economic returns from Balcarres are sustainable and the Richardson family are able to enjoy the fruits of their labour with the next generation taking over the responsibility for the operation in the very near future.

To assist them in working towards this vision, they have developed a farm plan that outlines their short-,



Ian and Pam Richardson. (Photo: Rachel Barker)



Fierce lancewood, a nationally uncommon small tree present on Balcarres.



Holmes Bay is part of Pigeon Bay, one of the many bays on the northern side of Banks Peninsula where Balcarres is located.



Remnant of regenerating forest covenanted on Balcarres.

medium- and long-term goals, and indicates the actions they need to take to achieve them. They have also developed a farm environmental plan that focuses on the diverse natural features of the property, including an action plan for each significant site.

Pam and Ian see biodiversity conservation as integral to their farming operation. Pam talks about the importance of native biodiversity as an indicator of the overall health of the property: ‘if the native plants and animals are doing well then the whole property is healthy.’ They have established a perpetual covenant with the Banks Peninsula Conservation Trust (see p. 108) over 27 ha of the best regenerating forest on the property and have fenced out grazing animals. Removal of grazing animals will encourage regeneration and they hope that in the long term, a tall canopy of the conifers totara and matai will again dominate, trees that were all but eliminated 100 or more years ago. They intend to fence off further areas of regenerating forest as they replace fences around the property, and are also considering more covenants.

Plant and animal pests are the single biggest threat to the farm’s biodiversity (and to farming values). Possums browse vulnerable native plants and also carry bovine tuberculosis, which threatens their cattle, while goats have the potential to devastate the forest.

Several invasive plants also threaten native plants if left unchecked (e.g. banana passion vine). Pam and Ian actively control possums and a number of plant pests, while feral goats have been exterminated. Stock damage to waterways has been reduced through a mix of fencing and use of water troughs, while they closely monitor weather conditions when break-feeding (strip-grazing) stock on cultivated paddocks to avoid soil damage. Native silver tussock grassland on the highest part of the property is managed to maintain tussock cover, which has value both for biodiversity and as shelter for stock.

Either on their own or working with others, the Richardsons are monitoring a range of environmental variables including native birds (as part of a Banks Peninsula-wide bird monitoring program), weta (a large, distinctive, forest invertebrate), vegetation (using photo-points), water quality and soil condition, as they recognise that monitoring provides direct feedback on the biodiversity consequences of their farm management. A 2008 local government assessment of the natural features of Balcarres paid tribute to the Richardsons’ commitment to biodiversity conservation, noting ‘The owners are exemplary conservation stewards of their property, highly aware of the natural values and keen to protect and enhance them.’

Mixed farming – Payneham Vale

Payneham Vale in the Frankland River region of south-western Australia is a farm with a difference, being known worldwide for its outstanding practical achievements in the protection and improvement of the environment.³¹³ Although owned by the Watkins family since 1908, Payneham Vale's date with destiny began in 1973 when the present generation of owners, Ron and Suzanne Watkins, noticed that the water in the house dam that used to water Ron's mother's vegetable patch and citrus was turning saline.³¹⁴

By asking questions, Ron soon worked out that the whole of the 552-ha farm was contributing to the salinity problem through runoff, subsurface flow over the top of the soil's B horizon, preferred pathways of water movement through the regolith and the rising water table. Although only receiving a modest average annual rainfall of 580 mm, excess water from upslope was causing water tables to rise lower in the catchment, which in turn was mobilising salt stored in the profile and polluting the dam.

As a result of asking more questions, Ron developed a system of banks and shallow drains across the whole farm to intercept the runoff and subsurface flow. The drains were dug into the top of the heavy-textured B horizon to intercept subsurface flow running downhill

through the lighter-textured A horizon. The banks and drains were constructed just off the contour (1 in 400 gradient) to channel excess water into newly constructed on-farm water storages, before it could move downslope and cause problems. As a further security, the Watkins planted and fenced native tree and shrub belts on the lower side of banks to intercept deeper soil water moving downslope.

This radical redesign of the farm had several far-reaching consequences apart from reducing the salinity problem. There was suddenly much more on-farm water than ever before. The banks, drains, fences and tree lines throughout the farm forced Ron to start farming on the contour, all in all arresting any water erosion. The newly established tree lines followed the folds and curves in the land and took care of the potential wind erosion hazard. The timber belts provided shade and shelter for the crops, pastures and livestock under the extreme summer and winter conditions of the Mediterranean climate. Every time there was a dust storm, the kilometres of tree lines caught the dust and fertiliser, which washed down into the soil with the next rain. And the small remnants of woodland on the farm, roadway and adjacent land were all linked with wildlife corridors, causing an explosion of small birdlife across the farm.



Aerial view of Payneham Vale in the 1990s, soon after its redesign and redevelopment. (Photo courtesy of Ron Watkins)



A shallow drain intercepting subsurface flow downslope with a shelterbelt planted on the bank on the lower side. (Photo courtesy of Ron Watkins)



A mature tree and shrubbelt at Payneham Vale, fenced from livestock. (Photo courtesy of Ron Watkins)

The abundance of water storages got Ron thinking about the concentration of biological activity around them. As resources permitted, he fenced several key dams from stock, reticulating water to troughs for stock water where necessary. Through natural processes, reeds now grow in and around these dams, ducks and waterbirds congregate and breed in them, and the Watkins use the nutrient-rich water to grow vegetables.

Today, the farm has about 16 km of double-fenced drains, and 25% of the farm area is off-limits to stock. About 10–15% consists of fenced tree belts,³¹⁵ another 10% of the farm is grassed waterways and the balance consists of fenced remnants of native vegetation and non-arable areas such as rock outcrops. ‘People say to me, “Ron, why don’t you let your sheep into the tree belts?” “No,” I say, “they’re too full of other things I want, like small birds, hornets and so on.” Diversity is the key to a sustainable environment because there’s so much interplay between the different elements of the farm ecosystem. If a farm is not diverse, it can’t manoeuvre itself to cope with all the changes from

one season or year to the next. It loses complexity and capacity to act as a self-organising system in the face of all the shocks nature and people throw up. It breaks down because it loses resilience. You need biodiversity.’

Ron’s redevelopment of Payneham Vale is grounded in his philosophy of integrated farm and catchment planning, which he developed into a successful consultancy business in the 1980s and 1990s. Ron takes a holistic environmental systems approach to new design challenges, analysing each component of the ecosystem in an interconnected manner: energy, water, air, soil, plants, animals and humans. ‘You have to look at each situation on its own merits, so the solutions vary with every unique environment.’

The hallmark of Ron’s approach is keeping an open mind and thinking flexibly when diagnosing a landscape and client’s needs. ‘Not many people take the systems approach. Experts will often emphasise just one or two things and ignore the rest. But it’s not just about controlling salinity, or using excess water, or getting birds

back. I start with the shape of the land. That determines the way water moves across or through the landscape. Everything flows from that.' Ron likens the systems approach to building a house: 'you need to start from the ground up. If you start with the roof or just focus on the windows, you're in trouble.'

In 1996 after years of thought and discussion, Suzanne and Ron decided to make Payneham Vale an organic farm. For Ron, the journey began in 1994 on a study tour to the USA. At the time, pregnant women and children were being advised not to drink tap water through a large part of the central US because of aquifer pollution with nitrate/nitrites from excessive fertiliser use. Ron's hosts in the Soil Conservation Service of the US Department of Agriculture took him to visit an organic farmer who had made money from 7–8 years of high-input conventional agriculture. When asked why he had decided to go organic, the farmer replied: 'My profits were falling away so I looked at my bank accounts and realised I had ended up working for the chemical companies. The quantities of inputs I had to use and their prices were all going up, with the result they were making far more money than me.' Ron also recalls 'the news report out of the US around that time about the increasing number of deformities in children from farms, presumably due to the exposure of farm workers to poisons.'

So for Ron, 'I was more and more drawn to organic agriculture because I didn't want to go down the conventional road anymore. I could see the result of the natural system of windbreaks we had implemented at Payneham Vale and the impact on insectivorous birds on the farm. So I thought, why threaten them with poisons? I had real concerns about pesticides and came to realise they may be unnecessary. Our grandkids started to arrive and we thought, what sort of future is one built on poisons to pass on to them? For virtually the whole of our evolution, we have been part of a natural system that clothed and fed us. I want to create and be part of that sort of living system; conventional agriculture has just become a killing machine. You need some pests, otherwise the beneficials don't have anything to eat.'

Today, the Watkins are NASAA organically certified, with 600 sheep for wool and prime lamb production and 60 head of beef cattle. They grow wheat, oats, field peas, olives, vegetables (onions, garlic and potatoes) and free-range eggs. The organic oats are sold overseas, and the



View of Payneham Vale from a fenced remnant stand of native vegetation with fallen timber in the foreground, providing wildlife habitat. The large dead paddock trees beyond the timber belt in the middle distance were ringbarked by livestock. (Photo courtesy of Ron Watkins)



A male golden whistler, Ron's favourite bush bird. Ron's aunt and sister are ornithologists and they keep tabs on the Payneham Vale bird community through regular bird censuses and bird-banding. (Photo: Lydia Paton)



Weeding an organic garlic crop at Payneham Vale.
(Photo courtesy of Suzanne and Ron Watkins)

rest of the produce is sold at the farmers markets every Saturday in Albany, freighted to Perth from Albany each week, or used on-farm. Weeding of the vegetables is done by hand, compost is used for fertiliser, and the hens, small birds and beneficial natural predators look after the insect pests.

Ron judges the free-range poultry enterprise as their best innovation in the last 10 years. 'We have just a few layers organised in three modules that are moved to a different part of the farm once a week. Each module has a mobile shed, water supply, fencing and self-feeders. The hens work over the vegetable crops and the land being prepared for cereals, eating the pests and manuring the soil. They're free-range so we have no serious disease issues, but you have to be diligent with the electrified netting, otherwise the foxes are ruthless. We get more orders for eggs than we can supply.'

The Watkins' customers at the farmers markets in Albany and through direct marketing in Perth provide a lot of the motivation to continue with niche marketing. 'We've been to about 530 farmers markets since they began in April 2002; we've only missed three. We sell most of what we take down. You develop a reputation



A module of free-range hens hard at work inside a mobile electrified enclosure. (Photo courtesy of Suzanne and Ron Watkins)

among a core of clients because they learn how much we care about our produce. Some cancer patients seek us out and come to purchase our lamb, beef and eggs ... the price doesn't seem to really matter. They know the difference between conventionally grown and organically produced food. I could tell you lots of anecdotes about the differences in quality and shelf life between the two.'

Plenty of challenges remain. Fortunately, Ron and Suzanne love farming and they get huge satisfaction from direct marketing their produce in Albany. The salinity is still around and some of the dams remain salty. Ron observes: 'I solved a couple of my clients' salinity problems out in the 450-mm rainfall country. The salinity is disappearing on their places.' The issue at Payneham Vale from Ron's systems perspective is that 'we're still not using all the rainfall that falls across the farm. Our annual pastures of rye and subclover are not using sufficient water: I want to add perennials like lucerne and chicory. We could also increase our water use with improved grazing management. With our current system of rotational grazing, the cattle are moved each week, but ideally we should have that down to every day or two to really drive primary production and increase pasture water use.' Reflecting on the work yet to be done, Ron smiles and says, 'I might need to leave a list of things to be done for the next lot!'

The Watkins' many accomplishments dwarf the challenges. The small family property has put three children through boarding school in Bunbury and is more productive today than at any time before. Suzanne and Ron have four delightful grandchildren, and although the organic farm business and direct marketing has meant less agricultural consulting, there's enough time to do *pro bono* work in the developing world. Ron has been to Kenya and Malawi five times in the past 3 years,



Ron and daughter Lisa harvesting organic olives at Payneham Vale. (Photo courtesy of Suzanne and Ron Watkins)

working with local farming communities to increase their agricultural productivity with good farming practices based on sound natural resource management. Back in Australia, prospective clients continue to ring up for advice after talking to satisfied former clients.

The Watkins' commitment to sustainable agriculture and environmental management has been recognised with numerous awards, including the WA Rural Achiever of the Year, the WA Department of Environment 'I Can Do That' Award, a UN Global 500 Award, a UN Environment Program Award, and a Landcare Individual Award. You can find Ron and Suzanne at the Albany Farmers Market every Saturday morning, where you can buy their certified organically produced meat, eggs, vegetables in season, citrus, olives and oil.

Sown pasture – Mangarara Station

Mangarara Station (610 ha) in central Hawke's Bay, eastern North Island, is a stunning example of what motivated farmers can achieve in integrating biodiversity conservation with sustainable farm management. The station runs 2300 breeding ewes and 600 trading cattle across a mix of river flats, rolling hills and steeper hill country. Greg and Rachel Hart have farmed the property since 1996 when they took it over from Greg's parents and together with their three children, George, Bill and Emma, are committed to sustainable farming, environmental enhancement and allowing people who don't otherwise have access to a farm to reconnect with nature and the cycles of farming life.

The Harts have developed a four-point vision:

1. To become a model of regenerative agriculture producing healthy, nutrient-rich food.
2. To balance the relationship between nature and production agriculture, by planting native and food producing trees, to restore ecosystems and to consider this balance in all that we do.
3. To open the gate and share the farm's resources to build community and model what is possible when we use more awareness and a clear intention to work co-operatively with each other and nature.
4. To develop an education and eco-accommodation centre as a home for RegenAG and a growing Family Farm community.



Greg Hart and his daughter Emma planting a native tree on Mangarara Station. (Photo: Greg Hart)

Mangarara Station has had a long farming history with the land first settled in the 1850s and as a result the hill country is largely devoid of native trees, although two remaining areas of native vegetation, a podocarp forest remnant and a lake and wetland, occur on the flatter land. When Greg and Rachel took over the property they started thinking about sustainable farming practices. With the QEII National Trust they covenanted the 10-ha stand of lowland mixed podocarp forest in 2004 and then in 2006 covenanted 35 ha at Horseshoe Lake, a wildlife refuge since 1957 and prime habitat for a diversity of water birds. Discussions are underway with the three neighbours who also abut the lake to fence off and replant the full lakeshore. This project is being supported by a range of government and non-government organisations, including local community and school groups. The lowland podocarp forest on Mangarara Station is an outstanding example of the tall kahikatea–matai–totara forest that would once have clothed much of lowland central Hawke's Bay but is now all but gone as a result primarily of Polynesian burning 600–700 years ago and then further clearance with European settlement. One of Greg and Rachel's objectives in developing a more sustainable model for land management is to restore these lost ecosystems and in doing so to create a beautiful place people will want to visit. They were the first recipient of funding from the Air New Zealand Environment Trust, receiving a



Lowland podocarp forest protected by a QEII National Trust covenant. (Photo: Greg Hart)



Developing restoration plantings with eucalypt plantation behind. (Photo: Greg Hart)

grant of \$450 000 over three years to plant 85 000 trees on the farm including a 40-ha gully they have retired. In 2009, family, volunteers and contractors planted and mulched 22 000 native plants including manuka, kanuka, hebes, cabbage trees, karamu and flaxes. Greg sees these plants as providing the shade and shelter for future forest canopy trees such as totara and kowhai that will be planted at a later stage.

As well as this direct conservation work, the Harts have also taken a novel approach to involving the local community in their farm. They have created the 'Family Farm'³¹⁶ – in essence a community of people committed to sustainable land management at Mangarara Station. Anyone can invest \$100 to become a member of the Family Farm and in doing so help restore the lost ecosystems by funding the planting of native trees as well as being part of the journey in converting a traditional sheep and beef farm to a model of sustainability. For this investment the Family Farm will plant a group of five native trees (which Family Farm members are encouraged to help plant), while members can visit and are kept in regular contact with progress in the Family Farm project through emails and the website. Although Mangarara Station is a business that supports the Hart family, financial gain is not their main focus. Any profits generated through the Family Farm concept are being invested in environmental projects, education and creating access opportunities for youth to visit the farm and in promoting sustainability in New Zealand agriculture more generally.



Ewe hoggets with lambs at foot and recently planted red alder established for two-tier farming. (Photo: Greg Hart)

Another exciting sustainability initiative is called 'Two Tier Farming'. This involves planting legume trees on rolling pasture land with the aim of achieving a diverse range of benefits including improving soil nutrient cycling through the presence of deeper root systems and the nitrogen fixing capacity of the associated rhizobium bacterium, to help sequester carbon, as shade and shelter for livestock (and by being deciduous allowing stock to graze between and below the trees), to provide fodder for livestock from foliage and seed pods, to be of value as timber and for aesthetic purposes.

The Hart family is now starting on another journey, this time with the aim of building an education centre and ecolodge. This facility will bring together people who realise that the way we live on the land, with nature and with each other, needs a complete redesign to guide us more gently into the future, and will also provide a home for the RegenAG programme in New Zealand. The focus of regenerative agriculture is on building soils, restoring watercourses, and encouraging biodiversity, while reducing dependence on outside inputs, improving livestock health and increasing farm yields and profitability. The Harts are committed to this approach and are applying the principles of regenerative agriculture on Mangarara Station.

Greg summarises their feelings about sustainability when he says: 'We are passionate about seeing this vision become a reality and excited about the opportunity to make a difference in the world, while sharing the journey with others who want to create change for a better future.'

Sown pasture – Paterangi

The Waikato in New Zealand's North Island is the historical heart of New Zealand's dairy farming and it is here, at Paterangi, that Roy and Annette Dench spent 40-odd years farming Jersey cows. The fertile peat and loam soils, reliable rainfall (1200 mm per annum) and equable temperatures make this some of the best non-irrigated dairy farming country in New Zealand. The pastures are dominated by ryegrass and white clover, while trees, mainly exotic, are largely restricted to shelterbelts and around homesteads. Although Roy and Annette have now retired and sold all but 20 ha of their property they are still strongly linked to the land and the conservation initiatives they instigated there.

The Paterangi property that Roy and Annette farmed wasn't always dominated by lush green pastures. Roy recalls that when his father settled at Paterangi in the mid-1930s, kahikatea, a conifer and the tallest tree in New Zealand reaching over 60 m, covered much of the property along with manuka (tea tree) and abundant blackberry and gorse. Roy's father spent many years clearing the farm of scrub and milling the trees. When working as a share-milker on the property in his own

youth, Roy remembers kahikatea being logged and comments, 'One of my jobs was to tally the logs in between milkings.' As a result of the logging there are now far fewer kahikatea remaining. But over their time on the property, Roy and his wife Annette worked hard to protect and restore the kahikatea stands. Roy fenced his first patch of kahikatea in the early 1970s and since then he and Annette fenced several more stands all of which have been covenanted with the QEII National Trust.

The scattered kahikatea stands across Paterangi farmland, and more widely in the Waikato, are mainly dominated by young trees, regeneration that arose from remnant old-growth trees surviving from the original forests. Most stands are now dominated by trees 100–150 years old, 25–30 m tall and up to 50 cm in diameter. Kahikatea is not the only tree species present, with tawa, pukatea and titoki common in stands on wetter soils, and totara, kanuka and kowhai in stands on drier soils. These tree clumps are important shade and shelter for livestock, and add aesthetic value to farms and the wider area, as well as providing habitat for a number of native birds including tui and bellbird



Roy on his old Paterangi dairy farm. (Photo: Katherine Tozer)



Vigorous regeneration in fenced-off kahikatea forest remnant. (Photo: Katherine Tozer)



Kahikatea forest remnant. (Photo: Katherine Tozer)

(honeyeaters), kereru (pigeon), morepork (boobook owl), silvereye, fantail and kingfisher.

As Roy and Annette discovered, cattle and kahikatea stands don't go together. Roy says that the first stand he fenced was previously used to winter cows, but the grazing destroyed the native seedlings and prevented forest regeneration. Fencing is essential as these forests evolved without the impact of ungulates, and domestic livestock eliminate the forest understorey vegetation, prevent canopy tree regeneration and modify soil conditions, especially through soil compaction.³¹⁷ Fencing off stands offered improved stock management and also helped the native plant species to regenerate, improving the quality of the forest understorey. Roy says that one of the biggest mistakes he made was to place fences too close to the trunks of the trees on the outer perimeter of stands. He says placing fencing further out gives more space for seedlings to establish and also provides more protection for tree roots: kahikatea has an extensive root system that can extend many metres away from the trunk and is vulnerable to trampling damage from cows.

Boundary fences now exclude stock and Roy and Annette also put in bait stations to control possums and rats. Roy also worked hard to eradicate rabbits but says that they were pretty hard to get at once they dug burrows among the kahikateas' massive root systems. Weed control was also an important part of remnant management because perennial weeds like privet,



Fenced planting with a mix of native and exotic trees along the side of the main farm access track.

Jerusalem cherry, ivy and wandering Jew pose a serious threat to native seedlings. These weeds are removed manually or using chemicals. As well as fencing of the remnants, Roy and Annette also fenced off and planted steep hillslopes and paddock corners to provide further habitat for native species, while coast banksia was planted with natives in shelterbelts to provide a nectar source for native birds such as tui to complement native nectar sources.

Since recently selling the property, Roy and Annette have built themselves a new house and started establishing restoration plantings on their remaining 20 ha. However, as the grazing is leased to the new owner of the rest of their old property, they need to be careful to balance the area restored against the grazing available.

Roy's interests in conservation have not been restricted to his own property and he has had an ongoing involvement in conservation work throughout the district. He is a Trustee of the Native Forest Restoration Trust and Deputy Chair of the Biodiversity Advisory Committee for Environment Waikato (the regional council). He has also played a significant role in the establishment of a captive kiwi breeding program at Otorohanga and has volunteered more than 20 years of service to Tongariro National Park, where Roy and Annette spent January each year. Roy was awarded the Queen's Service Medal for his commitment to community in the 2006 New Years Honours List in recognition of his contribution to conservation.

Irrigated arable farming – Kilmarnock

In Australia's premier farming districts where irrigation water is still available, land is valuable and appreciating in price as population and food prices increase and the climate heats up. On the Liverpool Plains of NSW, upward pressure on land values is further boosted by the recent expansion of the black coal and natural gas industries in the region. It is therefore important that floodplain irrigators who value nature are prepared to conserve biodiversity both for its economic contributions to their farm business as well as for its own sake.

Andrew and Heike Watson farm and graze the 2600-ha property, Kilmarnock (incorporating Brigadoon and a lease arrangement with the owners of Nandewar), at Boggabri, on the Namoi River in north-west NSW. They recently bought the farm from Andrew's parents, Robyn and John Watson, who still live in the family

home at Kilmarnock. Andrew was the NSW Farmers' 'Young Farmer of the Year' in 2004, 'Australian Cotton grower of the Year' in 2008 and named in Australia's top 10 young environmental leaders by the *Weekend Australian Magazine* in 2009. His aspiration? To invest in native vegetation restoration across the farm to encourage beneficial insects, microbats and birds, and their native habitats at Kilmarnock in order to pest-proof the irrigated cotton and dryland cereals that underpin the family business and his parents' cattle grazing enterprise.

Heike and Andrew gained their interest in biodiversity and the environment from Robyn and John. In their time at the helm of Kilmarnock, Robyn and John initiated an ambitious riparian restoration program along 35 km of the Namoi River,³¹⁸ one of the



Andrew Watson (left) showing Nick Reid the results of his parents' impressive river bank revegetation and stabilisation work on the Kilmarnock side of the Namoi River at low flow.



Darters (left) and little pied cormorants favoured the Watsons' riparian restoration on the Namoi River at Kilmarnock for nesting at the height of the millennium drought. (Photos: Rhiannon Smith)

major tributaries in the Murray–Darling system. The Namoi has fared badly since the 1960 construction of Keepit Dam, the main irrigation storage in the Namoi catchment, about 75 km by road upstream of Boggabri. Heavy grazing to the water's edge and cultivation to the top of the high bank, death of river red gums, and the regular summer release of irrigation flows have led to down cutting of the riverbed and bank instability, slumping and erosion along much of the river.

Beginning in 1990, the Watsons began to remove all the willows that infested the river banks and exacerbated the erosion. Once they were dispatched, they began on other woody weeds like osage orange and honey locust. They fenced off 3 km of eroding river bank from cattle grazing on their side of the river. They transplanted deep-rooted native tussock grasses like Australian vetiver and planted native shrubs and trees along and immediately above 2 km of the bank to stop erosion and restore riparian habitat. They also had snags realigned in the river channel to preserve aquatic habitat and reduce stream bank erosion.³¹⁹

Another initiative of Robyn and John's was to fence off a river red gum-lined ephemeral lagoon (billabong) and adjacent poplar box–grassy woodland as a conservation initiative and manage it for biodiversity. Parts of the area had become degraded and their hope was that by fencing the area, it would quickly recover. They soon discovered that putting up the fence was only the start of the management effort required to protect biodiversity. African boxthorn, a noxious weed, requires semi-continuous control where it comes up

beneath the poplar box in the reserve, dispersed by birds from the surrounding areas. Prickly pear is now starting to appear as well. Parts of the area had scalded red duplex soils as a result of past overgrazing and the hope was that these areas would heal themselves and return to perennial grassland after exclusion of domestic livestock. However, galvanised burr, a native weed, currently dominates these sites and has Andrew concerned as it appears to restrict perennial grass establishment. Other weeds, such as paddy's lucerne and lippia, continue to be a problem in grassland paddocks grazed by cattle near the river.



Robyn pointing out the bank-holding abilities of native vetiver grass. (Photo courtesy of John and Robyn Watson)

Robyn and John also have a passion for revegetation. With Greening Australia, they established 2 ha of mixed native tree and shrub plantings on the Kilmarnock floodplain for habitat, biodiversity and aesthetics. One drip-irrigated block of plantings was used by University of New England (UNE) PhD student, Adam Downey, for his research on the effects of cotton defoliants on native trees and shrubs. The research showed that none of the typical floodplain native tree and shrub species were killed outright by commercial cotton defoliants, but varying amounts and kinds of damage were registered by different tree species and the impact of sprays in successive years was cumulative. Species such as weeping myall were more resistant than river oak and belah.³²⁰

These blocks of trees and shrubs are valuable for local bird populations. Bird censuses by UNE researcher, Dr Rhiannon Smith, have shown that the trees and dense herbaceous vegetation between the rows provides habitat for several species of bird like yellow thornbill, brown thornbill, weebill, grey fantail, brown honeyeater and white-winged, variegated and superb fairy-wrens that otherwise struggle to find dense vegetative habitats on intensively grazed and cropped floodplains.³²¹

Heike and Andrew have caught the conservation bug from Robyn and John and initiated their own project in the farm's main irrigation storage. During a recent drought when water levels dropped to almost nothing, they took



Prickly pear in poplar box woodland surrounding the lagoon at Kilmarnock.

the opportunity to construct an island for waterbirds in the storage. They have already been rewarded with swans and other waterbirds nesting on the island. The family also fenced off a 1-ha remnant of floodplain yellow box woodland in their grazing country in 2000 to study the changes in understorey pasture herbage and see whether the massive old trees would regenerate. Unfortunately, no regeneration has occurred to date.

Andrew has persevered with habitat restoration, establishing more tree belts in conjunction with cattle movement laneways to link native and remnant vegetation across the farm, and is managing a 5-ha



Andrew's island in the main irrigation storage on Kilmarnock has hosted breeding black swans. (Photos courtesy of Robyn and John Watson, and Lydia Paton)



A planting of young eucalypts in a grassy buffer on the Namoi floodplain, between the irrigation and a dryland crop at Kilmarnock. (Photo courtesy of Robyn and John Watson)

remnant of open woodland as habitat and a refuge for microbats and beneficial insects. He has resisted the temptation to spray his cotton with insecticides for the past 3 years to build up the populations of ‘beneficials’. The no-spray policy results in lower yields (10.5 bales/ha, average for 2008–10) when benchmarked against high-input industry peers (14 bales/ha). However, it is also less costly, returning gross margins of \$2500–3500 per hectare and placing Kilmarnock among the most profitable producers, while conserving beneficial fauna and underpinning the farm business with greater ecological resilience.³²²

Andrew observes, ‘As we continued to invest in activities like river bank regeneration and tree lines, we saw a number of benefits that we hadn’t anticipated, like increasing numbers of beneficial insects and bats.



Variegated fairy-wrens, like this female, as well as white-winged and superb fairy-wrens have colonised dense native shrub and tree plantings on Kilmarnock, close to the Namoi River. (Photo: Lydia Paton)

This is encouraging us to invest further. The thing is, we don’t know what further environmental benefits and services we might accrue, but we believe there will certainly be more.’

Floodplains in irrigation districts are extraordinarily valuable real estate, especially when underlain by coal and natural gas. Not surprisingly, natural grasslands on fine-textured alluvial plains in north-west NSW are a critically endangered ecological community, listed under both state and federal legislation. That farmers in these situations consider nature from a commercial viewpoint and look after biodiversity for its financial benefits is heartening. That they set aside land for conservation and biodiversity at their own expense with no expectation of remuneration because ‘it is the right thing to do’ means that we are all beneficiaries of their stewardship.

Irrigated intensive cropping – Harts Creek

'Harts Creek' farm is typical of many mid-Canterbury mixed cropping properties, with two significant differences – the property is 100% organic, gaining its Bio-Gro organic certification in 1986, and because of its extensive riparian restoration plantings. Tim Chamberlin and Rose Donaghy farm this 180-ha property, which runs some 600 breeding ewes (traditionally Romneys but now changing to Wiltshires), while some 75% of the farm is cropped each year. Crops grown are diverse and include onions, cereals (wheat and barley), carrots, sweetcorn, peas, linseed, echinacea and pasture grass seed. Tim and Rose's involvement in organics has stemmed from their interest in the environment, their joy of adventure, a desire for niche markets, and their concern for the sustainability of their farming system. This has led them to making a number of changes to how the property has been traditionally farmed, one of which has been a focus on establishing native riparian plantings.

Two spring-fed streams, Harts Creek and Birdlings Brook, cross their property. These have now been fenced to prevent stock access and riparian strips of native plants and production trees established. Some of the more established areas now have a walking track through them so that visitors can gain an idea of what the area might

have been like before the onset of intensive European farming. In addition three ponds have been established for wildlife enhancement, especially for birdlife. And the riparian plantings are working – for the first time in Tim and his father Peter's memory, the native bellbird was present on the property in 2009 and again in 2010, surely testament to the enhanced habitat quality provided by the plantings!

Tim grew up at Harts Creek which had been farmed by his family for several generations. He met Rose in London while travelling. Although she was from Adelaide, Tim was able to convince Rose to come back to New Zealand and Harts Creek with him in 1984. Both Tim and Rose are passionate about the need to bring nature back to Harts Creek. Tim's impression of the Canterbury Plains landscape he grew up with is akin to the images on TV from *Little House on the Prairie*. He loves nature but also saw restoration plantings as a 'smart' thing to do – something to distinguish Harts Creek from other farms in the area and perhaps a potential opportunity for the future. Rose completed a university landscape architecture course which opened her eyes to the importance of native plantings and sees herself as quite a purist when it comes to what should be planted.



Tim Chamberlin and Rose Donaghy. (Photo: Tim Jenkins)



Harts Creek with restoration plantings and eucalypt woodlot behind.



Organic carrot seed crop at Harts Creek. (Photo: Tim Chamberlin)



Mt Cass farm with native forest remnant growing on limestone in the foreground.

They asked a local botanist to prepare a report on what plants might be appropriate for the Harts Creek area, but are quick to acknowledge that much of the impetus for starting into native riparian plantings came from Tim's father, Peter. Peter had been a 'tree planter' for many years, establishing shelterbelts of exotic and native trees and amenity plantings on the property. He has a real love for trees and instilled this in Tim and Rose. The other key factor in starting the plantings was Gunnar Lundaal, another 'man of the trees'. Gunnar had worked on Harts Creek on and off for a number of years, but his real passion was tree planting and his enthusiasm and knowledge was essential for the restoration program.

The initial plantings were undertaken on a gorse-infested section of Harts Creek – Tim and Rose had wanted to do something there for some time as it had little farming value and was a bit of an eyesore. Rose was keen to be as 'true to what had been there originally' as possible so planting natives was the right thing to do. Funding came out of their regular farm budget, and restoration continued for the next 20 years focusing on both Harts Creek and Birdlings Brook. Harts Creek Farm is now effectively fully planted. A great diversity of species have been planted including seral tree species such as kanuka and pittosporums, key food resources for native birds like harakeke (New Zealand flax), cabbage trees and kowhai, and old-growth forest trees like kahikatea and beech. In places the plantings are now 5 m or more tall and regeneration is starting to occur in the understorey.

But in many ways the riparian restoration work at Harts Creek is just the beginning of the story. In the late 1990s, a local fisherman called in at Harts Creek distraught at the condition of the stream but impressed with the plantings that Tim and Rose had done. Upstream from Harts Creek farm, dairy cows and deer on other properties had free access to the stream and were a major cause of the poor water quality. Tim's father Peter, now retired, was able to take up the challenge. Working with his neighbours he formed the Harts Creek Stream Group, and with help from Environment Canterbury (the regional council) has been able to attract \$160 000 of funding to help restore the full length of Harts Creek involving almost all of the local farmers. Getting the upstream dairy cows and deer out of the river was pivotal to restoring the whole Harts Creek riparian zone. Today the stream is almost fully restored, with the local Lions Club recently installing a walking track and bird hide along the lower reaches. But Harts Creek Farm was the catalyst for this whole project.

With two partners, Tim and Rose have recently purchased Mt Cass, a large (2300 ha) sheep and beef property in North Canterbury, with significant natural values including coastal turfs and shrubland, limestone outcrops and old-growth forest remnants. As well as farming this property organically, they are keen to start integrating sustainable biodiversity conservation into their management.

Cropping to restore soil – Connewarran

Jenny and Richard Weatherly found themselves in an unenviable position when they took on ownership and management of the Weatherly family property, Connewarran, near Mortlake, western Victoria, on 1 February 1985. The 1982–83 drought and the intervening period had left the property in a disastrous state. Jenny and Richard found themselves with a degraded soil, water and pasture base, no yards, no homestead, no shearing shed, no plant and no livestock!

‘We began with a dry sheep operation, and by October 1985 we had a shed and were shearing,’ Richard recalls. ‘This may have been viable, but trying to buy stock coming out of the drought was an issue. The first sale I attended I had a budget of \$15 per ewe and \$12 for wethers. The lot I was interested in that day sold for \$48.50 a head. We were blown out of the water by the prices. So we started with the worst Merino flock in Australia, mainly culls from farms across the region and the tail end of other breeds, as well.’

Apart from immediately having to go into debt to purchase stock and rebuild the infrastructure, the 1680-ha farm was basically 11 paddocks that were historically swamp land, with large areas that had never seen superphosphate.³²³ Pastures that had been sown in 1970

had had little done to them since, so carrying capacity was low. Other than three tiny tree plantations located in places that had no influence over the rest of the property, the farm was just overgrazed open native pasture exposed to the elements, with light topsoils eroding in the wind. The river red gums scattered across the property were starting to die, and the water in the 8 km of Hopkins River frontage was turning salty.

Richard says that it was fortunate that ‘both Jenny and I knew the place we were taking on well ... I grew up there and Jenny had known the property for the preceding 10 years. We knew we had to improve three main elements of the farm operation to succeed: shelter, the drainage and fertility of the pastures, and livestock genetics.’

‘Although it might sound strange, our initial investment was in direct seeding native vegetation to improve shade and shelter,’ observes Richard. ‘There was no place on the farm to raise lambs, and no reasonable protection to reduce moisture loss from the pastures. Since it’s quick to change genetics and improve pasture, we reasoned the trees would take longer. We thought that by the time the others came into full swing, the trees would be up and able to influence the other improvements. But the increase in biodiversity happened quicker than we imagined. We saw biodiversity improvements within 18 months of revegetation and could see the impact of improved shade and shelter on livestock production within 3 years.’

Cropping

Connewarran is situated on the Hopkins River and the waterlogging-prone soils vary from clays to duplex profiles with a sandy A horizon. During the long winters, the ground becomes waterlogged after rain due to the high clay content and low permeability of the subsoil, resulting in complete crop failure on flat or gently sloping ground without drainage. More than half the property needed topsoil restoration.

Richard remembers that ‘our paddocks consisted of infertile eroding soils, seasonally waterlogged country and overgrazed native pastures. They were a millstone



Connewarran, as it was, in 1985. (Photo courtesy of Jenny and Richard Weatherly)



Looking over the top of a direct-seeded shelterbelt across an ephemeral wetland to other shelterbelts at Connewarran. (Photo courtesy of Jenny and Richard Weatherly)

around our necks, holding us back. We needed cropping to rescue the country that had lost its topsoil to wind erosion in the drought. We did some cropping early on to try and recover eroded country. Initially we grew oats to improve the degraded soils, increase soil aggregation and organic carbon, and redevelop topsoil on the eroded light sandy loam country. But history showed that cropping in our district was going to fail four years in five because it was too wet. My father always said about this country, “don’t try to grow wheat, and don’t try to grow Merinos.” We ended up doing both but his point was well made. The climate and soils militate against both unless you do something different.’

‘We needed a low-cost way of improving our soils, pastures and drainage, and generating cash all at the same time,’ explains Richard. ‘We had two options, lease extra country and farm it ourselves, or lease our own country to someone who could make use of it. We opted for the latter and found a share farmer in the early 1990s who was experimenting with raised bed cropping. Leasing our country was about risk management. We had an income stream from some of our least viable country and at the same time, our topsoil fertility was being raised. We ended up leasing about 40% of the farm and the fertility of the soils went from 1–4 parts per million Olsen P [phosphorus] to 20–25 parts per million.’

Raised bed cropping was developed in south-western Victoria in the 1990s to overcome waterlogging and improve soil structure on cropping soils under high rainfall conditions (>550 mm per annum).³²⁴ The share farmer and Richard settled on an annual cropping program of wheat, barley and canola in a three-year rotation to lift fertility and earning capacity of the best soils.

‘We ended up cropping for 14 years, the first crop being sown in 1997,’ recalls Richard. ‘Raised bed cropping was just an interim measure on the way to well-drained, highly fertile, improved pastures for raising lambs. It took about two to three years to recover topsoil fertility in a paddock. We don’t do any cropping now, we are purely a pasture operation – a sheep and cattle station.’



‘Humpin’ and hollerin’’: grading the raised bed Connewarran paddocks into ‘lands’ (left) and an oats crop sown into the humps and hollows (right). (Photos courtesy of Jenny and Richard Weatherly)

‘We found that horticultural raised bed cropping doesn’t work with livestock and pasture because it’s hard to get on to for spraying in winter, unless you fly on urea. It’s impossible to fight fires on, and fires are an issue in this district. And the raised beds are shocking for stock: prime lamb mothers get cast in them and heifers go down in the furrows and can’t get up. So we graded the raised bed country into “lands” or gently graded “humps” and “hollows”. At Connewarran, a height differential of 400 mm from the top of the crown to the bottom of the trough over a 15.1 m span gave the best improvement in productivity for the least movement of soil.

Richard observes that ‘a pasture grass like phalaris, which is tolerant of waterlogging and dries out the soil to depth, does well under these conditions and you still get some aerobic production of grass in winter because the water drains away. You can’t run cattle when it’s very wet because they pug the soil. But the lands harvest the water, which we store on-farm and use for stock. We implemented a keyline system to harvest water across the whole place to maintain aerobic soils and pasture production even in winter, rather than putting up with waterlogging and leaching of nutrients into the subsoil.

‘Once we got the fertility up it was necessary to redevelop the soil biodiversity. In our case, we added to it. We got CSIRO Entomology’s Geoff Baker to help us survey our soils for earthworms because our earthworm density of 163 per square metre was a bit low. We went to Woolnorth at Cape Grim, north-west Tasmania, and brought back 8000 long-worms, a long deep-burrowing European species. We had southern worms and grey

worms, which are surface dwelling, but we needed burrowing long-worms to improve soil structure and infiltration at depth.’

Richard and Jenny developed 1000 ha of the farm as improved pasture (phalaris, cocksfoot, fescue and subclover) stocked at 10–14 DSE/ha. Until recently, they ran 10 000 fine wool Merino sheep, including a commercial flock of 4000 ewes and 700 stud ewes,³²⁵ and 280 Hereford–Simmental-cross cows for beef production. Apart from a little bit of native pasture maintained as a conservation initiative, all the pastures are sown to phalaris, cocksfoot, fescue and ryegrass, with a little lucerne around the homestead for fire protection and the stud sheep and cattle.

Shelter, biodiversity and ecosystem resilience

Biodiversity rates highly at Connewarran, not because Richard is a naturalist and internationally acclaimed wildlife and landscape artist, but because Richard and Jenny are farmers focused on profitable livestock production. They believe that fundamental to their survival and prosperity is the need to sustain a biodiverse resilient farm ecosystem, from which they harvest the surplus.

Richard developed his own tree seeder for direct seeding of native trees, shrubs and herbs before it became commonplace to plant native windbreaks on farms. After some modifications with Thornton Engineering, the result was the ‘Eco Tree Seeder’, which is sold commercially. It is a versatile stump-jump seeder, with a three-point linkage, suitable for a wide variety of soils from heavy clay to sand and rocky soils. It has a scalping blade followed by three adjustable discs for seedbed preparation, a seed box with the option of placing fertiliser from a second box below the seed, a press wheel and a compactor roller.

At Connewarran, the Weatherlys have direct-seeded 45 km of wide interlinked shelterbelts across the farm to provide shade and shelter for livestock and pastures and to re-establish a native ecosystem for natural pest control across the farm. ‘We plant nodes or blocks of bush that are at least 10 hectares in size. These are not sustainable in their own right but we interconnect them with planted corridors up to a 100 metres wide over the whole place. We are 50–60% of the way through developing our on-farm ecosystem.’



One-year-old Connewarran stud rams. (Photo courtesy of Jenny and Richard Weatherly)



Richard checking foliage for the presence of beneficial insects in one of the direct-seeded shelterbelts at Connewarran. (Photo courtesy of Jenny and Richard Weatherly)

The planted shelter has made a tremendous difference to the farm's bottom line.³²⁶ Richard has examples where stock and pasture shelter has lifted lambing percentages by 11%. 'There is no doubt in my mind that a fundamental way to make money is by improving your asset, for example, by providing protection for the stock from wind and sun,' says Richard. 'By providing shade and shelter, both animal and pasture performance are improved. The temperature is generally about five degrees Celsius warmer under shelter than in the surrounding open paddocks, reducing ewe feed requirements and lamb deaths through exposure. A bare shorn sheep in a 5 km/hr wind will use double the energy to stay alive than in still conditions. And it's the same for the pastures. Less wind means less evaporation and less stress on grasses, so there are big production gains. It's not being a "greenie," it's just good business management.'

The shelterbelts contain anywhere from 65 to 120 species of plant, not all of them sown. According to Richard, 'because of the way we sowed trees – scalping the topsoil prior to direct seeding rather than using triazine herbicides – we came up with native understorey species under the trees that we didn't know were there, such as *daviesias* and *pultenaeas*. The combination of fencing out after 30 years or more of sustained grazing has given us a good response of native shrubs and herbs.'

Richard sows mostly native plant species although not necessarily those indigenous to the local area. He uses 'analogue forestry,' choosing native species to mimic the functional ecology of a local indigenous ecosystem with a wide diversity of life forms and floral morphologies

to attract a diverse range of animals, such as mammals, birds and insects to control pests. 'The river red gum that is regenerating most on the farm at present is not the local provenance, which is often reduced to measly wizened trees on the most desperate country, but the Silverton [western NSW] provenance.'

Richard has learnt a lot about insect biodiversity, predator-prey relations and ecological balance. 'My aim is to create a balanced ecosystem. Insects are an important part of that ecosystem. I may have to accept some insect predation on trees and crops but I should be able to avoid any serious 'plague' outbreaks through simple biological control. If problem insects are being predated by other insects, their populations will stay under control.' And it works.

Eucalypt sawflies are a case in point.³²⁷ They are a common pest in southern Australia and can completely defoliate individual trees. 'The key to controlling sawfly is having a nectar resource to attract the predatory wasps and tachinid flies that predate the sawfly larvae,' Richard says. 'Flowers are the most obvious nectar source, but they are not around all year. Insects also feed on nectar excreted from the tiny glands of acacias. Sawflies are generally pests of open woodlots and ornamental trees, so a greater variety of trees and shrubs also helps reduce their impact.' Richard has found that as the direct-seeded vegetation on the property has built up, the sawfly problem has diminished, partly because the increasing density of avian predators like cuckoo-shrikes and other bush birds contribute to the control effort.

Parasitic tiphiid wasps live in the shelterbelts and are part of the Weatherlys' pest control arsenal. 'Some



An adult sawfly and lerp on a eucalypt leaf in a Connewarran planting. (Photo courtesy of Jenny and Richard Weatherly)

tiphiid wasps control curl grubs [scarab beetle larvae]. The female wasps are flightless and look like ants. They burrow down into the soil to lay their eggs in curl grubs. The process is dependent on nectar. The female wasp needs fertilising after laying only one or two eggs so the male collects nectar to feed her during copulation. The male must feed on nectar every day but is only a short-range flier, so a dense crop of nectar-bearing trees or shrubs nearby is essential. Controlling curl grubs has a double benefit. The grubs damage pasture by eating pasture roots, then hatch into scarab beetles, which defoliate eucalypts and contribute to dieback. Adult scarabs have their own parasites. Tachinid flies lay their eggs on the head and thorax of the beetles. On hatching they burrow into the beetles, quickly killing them.' Small parasitic flies and wasps are also important in controlling the gum leaf skeletoniser, which can seriously damage sapling eucalypts. Small flies and wasps parasitise the larvae of the skeletoniser; their own larvae develop inside the moth larvae, killing them.

The shelterbelts have collateral benefits for other animals, with swamp wallabies and koalas inhabiting the kilometres of novel habitat. The shelterbelts are so wide and contain so many direct-seeded plants that some tree and shrub deaths are a cause for celebration. Plants that have died and toppled over build up ant activity on the ground, which brings in echidnas. 'My father never saw an echidna here in 70 years. Now we regularly see them.'

Given the swamp-prone nature of the landscape, Richard and Jenny have made a virtue of necessity and manage more than 50 ha of Connewarran as wetlands in



Echidnas have recolonised the farm since Jenny and Richard revegetated Connewarran with native wildlife corridors. (Photo: Karl Vernes)

15 different locations.³²⁸ One 30-ha ephemeral swamp fills in high rainfall years, producing a shallow wetland that attracts a wide variety of waterbirds, some of which help control pest insects (e.g. scarab beetle larvae, grasshoppers and black crickets) in surrounding pastures.

Richard has observed a relationship between the wetlands and flystrike. 'Flystrike in our sheep is much less common in years when the wetland fills.' The huge increase in aggressive insects like dragonflies near acacia plantations is critical, '... since dragonflies are a tremendous predator of blowflies and a very valuable asset on a wool growing property. The dragonflies breed in the wetlands and hawk up and down in the lee of the black wattle rows, catching blowflies that are attracted by the acacia leaf nectar or the shade.'

Central to Jenny and Richard's thinking about building their biodiverse resilient farm ecosystem is its long-term sustainability at district and regional scale. In Richard's opinion, 'the importance of what we do at Connewarran counts for nought unless our farm ecosystem is interconnected with similar biodiverse ecosystems at landscape scale and further. By 1994–95, our farm-wide corridors of trees and shrubs were linked to similar plantings on neighbours' properties as well as with similar work along the Hopkins River and its tributaries up to 20 kilometres away.' When Richard was chair of the Watershed 2000 group, they developed a plan to link remnants of natural ecosystems through south-western Victoria from the Otways to the Grampians over a 200-km distance, 40 km wide, using the river systems



A curl grub, partially consumed by the larva of a large scoliid parasitoid wasp. (Photo courtesy of Chris Haywood and Gus Campbell)



A shallow wetland on Connewarran, providing habitat for spoonbills and ducks. (Photo courtesy of Jenny and Richard Weatherly)



A waterhole along the Hopkins River at Connewarran. (Photo courtesy of Jenny and Richard Weatherly)

and drainage network as the skeleton of a region-wide network of ecosystem corridors and interconnections.

At Connewarran, Jenny and Richard have fenced off virtually their entire length of the Hopkins River, due to increasing levels of salinity in the river and overgrazing and erosion of the riparian zone by livestock. ‘We had noted a rise in the salinity of the river water,’ says Richard. ‘So to water the stock efficiently and provide the stock with clean water, the best thing we could do was to shut them away from the river altogether and water them from another source. There is a strong correlation between water quality and livestock productivity – up to 22% more cattle production with clean water.’ Stock watering is now from concrete troughs or dams (troughs are fed from reticulated water, sourced from dams or underground bores).

Since fencing off the river – an ongoing process for the past 20 years or so – the regrowth of native trees including red gums has been impressive. Fencing both banks has created a wildlife corridor and a series of wetlands that link various parts of the property (in conjunction with shelterbelts and tree plantations). A marked increase has occurred in native fauna along the river (e.g. with more breeding platypus) as well as greater numbers and diversity of birds, reptiles and mammals, in synchrony with the general increase in birds, reptiles, mammals and beneficial insects across the whole property. Richard’s species lists for Connewarran tally 210 birds (including introduced species), 45 mammals (including exotics) and nine species of frog.

Fencing out the river has been all good for livestock production, from Richard’s perspective: ‘no more bogged livestock, no more access to salty water, and no more boxing of stock across the river. However, it does allow phalaris to dominate. And it divorces the river from the farm because you’re not dependent on it for stock water anymore. I knew the river intimately, I grew up down there, but my children will never know it. I go down to the river these days as a naturalist, not as a farmer.’

Richard recalls an experimental demonstration of the resilience that he and Jenny have achieved with their biodiverse farm ecosystem. ‘Fifteen years ago, the local fertiliser representative wanted to know what my trick was, why I never had to spray my crops to control scarabs, lucerne flea and diamondback moth. I explained



Robber flies are important natural enemies of pest insects in Connewarran shelterbelts. (Photo courtesy of Jenny and Richard Weatherly)

how we had built up our farm's natural pest control by restoring native vegetation, corridors, wetlands and the Hopkins River, and relied on all manner of predators and parasitoids, such as ladybirds, robber flies, wasps, tachinid flies and so on. We ran an experiment to help convince him by raising weaners on a rape crop. As pest numbers built up at Christmas, he wanted to spray. I persuaded him to delay a little longer and by early January, the natural enemies had done their job. After that, I helped him design a native vegetation farm ecosystem for his own property.'

Sheep genetics

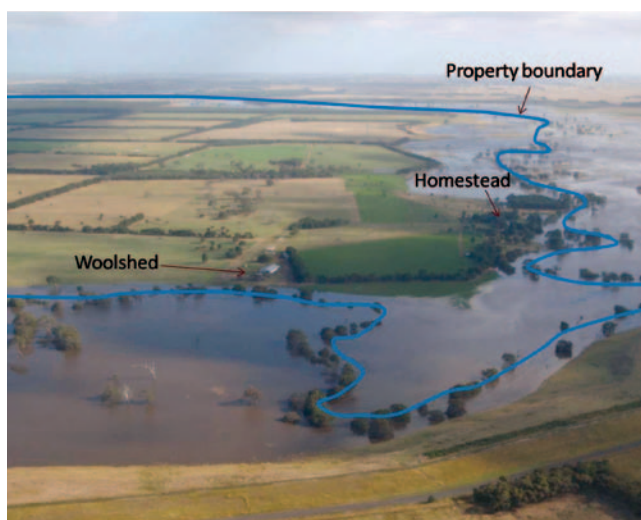
The Weatherlys started using an elite wool selection system early in their breeding program, selecting rams visually for stature and style, feel and handle of the wool, skin type and follicle development.

According to Richard, 'The original sheep here were a low production, high micron type, whereas we wanted robust grazing machines that just want to have lambs and grow lots of quality fibre as well as mutton. We needed to get rid of tight skins to grow free-flowing, long stapled, bright, white, deeply crimped wool on a big well-framed body.' To avoid penalties for overly long staple, shearing at Connewarran now occurs every 8 months for the commercial flock and every 6 months for the stud. The commercial flock ewes cut 6.8 kg of 18.5- μ m wool, yielding 85 kg/ha per shearing, and the stud ewes are a little finer (18.3 μ m).

For a time, the Weatherlys tried high-input, high-productivity, livestock production touted by some in the private and public sectors, but Richard and Jenny found it very poor for animal health. 'The levels of protein in the sheep diet were almost lethal,' observes Richard. 'So we pulled back to 10–12 DSEs per hectare and are happy to stay there, with higher profitability.'

Connewarran today

Today, the property is devoted to stud genetics production. 'We are both over 60 and approaching retirement,' muses Richard, 'and we've been debt free for a few years, so we are not looking to work harder than we have to. Two years ago we leased country to a leading Angus stud. We think that the highest return



Aerial view of Connewarran showing the network of planted shelterbelts and the Hopkins River in flood in 2011. (Photo courtesy of Jenny and Richard Weatherly)

we can get is from selling genetics, not commodities. So we have a Merino stud, a small commercial flock, and the rest is leased to Angus stud production now. Our son is preparing to take over in the next couple of years.'

'Across the property we maintain 130 acres [53 ha, or 4% of the farm] as native grassland, as an indication of what the country was like. We have 7% in wetlands in a wet year and 12% under native trees and shrubs, which also has a native understorey as most of the revegetated country was never improved, and the Hopkins River is fenced off. The rest is improved.'

Native pasture on Connewarran has been preserved by four generations of Weatherlys. 'The last area of 130 acres of native pasture was degraded by overgrazing and drought like the rest of the property, but it still has substantial natural values. There are large amounts of kangaroo grass and wallaby grass as well as clover glycine, a range of orchids – donkey, onion and sun orchids – featherheads and pale sundews. Unfortunately the native country is being invaded by creeping bentgrass and fog grass.'

Richard urges anyone looking to make similar changes to be confident and not afraid to have a go. 'We have found that we can put a lot of land under some form of ungrazed vegetation and still generate an increased income.' And the Weatherlys and local biodiversity are the better for it.

Farm forestry – The Hill

Vicki and Jon Taylor, their son Michael, his wife Milly and their daughter Katherine, are the fifth and sixth generations of Taylors at The Hill on the New England Tablelands in northern NSW. The Taylors arrived in 1840,³²⁹ and have grown fine wool and beef cattle there ever since. Vicki and Jon's philosophy was that the family property was their 'tools in trade' to make a living from and to be passed on in as good or better shape to the next generation. In the last few years, Michael and Katherine have taken over running The Hill and nearby East Oaks.

The Hill is a very different farm today to the one Jon grew up on. For one thing, the farm now has a radiata pine softwood enterprise, based on harvesting about 1.5 ha of timber each year, with its own sawmill. In the 1950s when Jon was young and his father, Walter, was operating The Hill, the property retained a 25% cover of native timber, which was about right in terms of livestock shade and shelter. However, it all changed in 1956 when aerial applications of fertiliser and pasture seed began, with 125 kg/ha of superphosphate being applied annually at The Hill until the mid-1970s.³³⁰

'The supering led to increased stocking rates, which combined with the clearing, led to such a change in the ecology that things got out of balance pretty badly,'

recalls Jon. 'A lot of trees died in the 1960s, being defoliated two or three times a year by massive insect attacks. The surviving trees were so sick, they didn't set seed, and even if they had, the seedlings would have been grazed by the increased stock numbers ... So between 1967 and 1990, nothing came up anywhere, and the tree ecology all fell in a heap.' In the late 1960s, Walter and Jon began to clean up all the dead timber and sow fodder crops and pastures. Apart from the exposure to the elements, the farm just didn't 'look right' anymore.

Once the worst of the dieback was over, Vicki and Jon pioneered a tree planting program that continues today. They commenced on a large scale in 1979, planting 20 000 bare-rooted radiata pine seedlings. 'Each year, we like to plant one to two hectares, non-commercially thin one to two hectares, prune one to two hectares, commercially thin one to two hectares, and eventually finally harvest one to two hectares,' says Jon. Pines that Vicki and Jon planted in 1979–80 have been commercially thinned and will be ready for final harvest around 2015, with a continuous supply coming on-stream thereafter. The beauty of timber is that a crop can be harvested when the price is right or the income required.

Tree planting at The Hill has led to much more than just the softwood timber enterprise. The first bare-rooted pines planted cost Vicki and Jon just 15 cents each. But by 1982, they were planting significant numbers of more expensive native and other exotic trees, as well, at \$2 per tube. For efficiency, Jon developed a mechanical tree planter, allowing them to operate a contract tree planting business for several years. By the time landcare arrived in 1990, the need to conserve and restore native vegetation for wildlife and biological control agents to counteract dieback was starting to be recognised. But native trees and shrubs were still being propagated as expensive tubestock. After a trip to the USA, Vicki and Jon introduced the Swedish Hiko tray system to Australia in 1991 and established their own company to sell tree planting equipment.



Milly and Michael with the seventh generation of Taylors at The Hill, from left, Nina, Lydie and Remy. (Photo: Michael Taylor)



One of the few stands of native trees (New England peppermint) to escape dieback at The Hill. Eucalypts often fare better in drought years in the region, due to a reduction in insect numbers. This photo was taken in December 2004, shortly after drought-breaking rain.

More than 30 years after the initial pine plantings, the Taylors have planted about half a million trees at The Hill, bringing tree cover back to about 15–20% of the farm, almost all of it planted. They plant up to 3 ha per year, half radiata pine and the rest a diverse mix of native and other exotic trees. ‘We want as much diversity as we can get. To reduce tree loss, we want species with good survival and that are habitat for a diverse range of insects and birds in order to beat the beetles and their defoliation,’ says Jon. Planting designs have varied from boundary and mid-paddock windbreaks and blocks of trees, to riparian corridors and engineered woodlands. The last mentioned are whole-paddock contour plantings of double rows of natives and pines for commercial timber, long-term shade and shelter, and biodiversity (i.e. wildlife habitat, and for ecological balance and biological control). The Taylors’ engineered woodland innovation started a movement in New England to return timber to the whole of the pastoral



Aerial view of the whole-paddock plantings of radiata pine and native trees on the contour that Jon and Vicki Taylor pioneered. These ‘engineered woodlands’ have since been planted on many other farms in the region. (Photo: Michael Taylor)



Block planting of high-pruned young radiata pine at The Hill.
(Photo: Jodie Reseigh)

landscape, not just around paddock boundaries or for sheltering a small proportion of paddocks.³³¹ There are now some 30 farms in the district trialling various engineered woodland designs.

Vicki and Jon were concerned about the condition of Terrible Vale Creek, which runs through The Hill. It was overgrazed and stream flows had scoured out a gravel bed, leaving a string of bare-sided waterholes and eroding banks. After an initial successful tree planting on the creek, they decided to fence out a long section, replant it and manage it as a separate paddock, with dramatic results. According to Jon, ‘The creek is disappearing! ... the banks have grassed up, reeds have come back, and the vegetation retains sediment ... in each flood, silt is deposited on the plant surfaces in the riparian zone. This has a filtering effect on the water and the silt is free fertiliser! The pools used to be quite muddy and there used to be a lot more algal blooms, but most of the time now, the water is quite clear ... Long Frog paddock is very good for grazing, especially with weaners because it grows a lot of the best grasses and it’s well sheltered by the trees we have planted.’

Since the Taylors started planting trees and fenced off the creek, they have observed that lizards, snakes, echidnas and birds have all fared better with the increased tree and grass cover. Koalas returned to the farm in 1995 for the first time since the 1860s, and since then many have been seen. ‘When thinning the pines, we’ve had to leave trees because koalas were in them.’



After fencing along Terrible Vale Creek, planting trees, and managing grazing along the creek, the waterway became revegetated and turned into a series of waterholes.

Bird surveys have shown that the exotic tree plantings have almost as many bird species and individuals as the native plantings at The Hill or the native timber at nearby East Oaks.³³² Three declining woodland bird species (restless flycatcher, white-browed woodswallow and rufous whistler) have been recorded at The Hill, with the rufous whistler preferring the pines.

Vicki and Jon are cautious but positive about the financial benefits of their transformation of The Hill and East Oaks. ‘We believe our properties are capable of the same level of production as they were before we started tree planting. In other words, at the very least, the extra grazing production resulting from the shade, shelter, biodiversity and cleaner water compensates for the land being taken out of production with trees.’ Through their revegetation efforts, the Taylors have broadened their commercial options (e.g. the sawn timber enterprise, the tree planting and equipment businesses, Christmas trees, treated pine posts, etc.), and reduced their risk of exposure to extreme climatic events, further dieback and falls in the price of wool and beef.

Michael, an engineer by training and one of the new generation of managers at The Hill, agrees with his parents’ assessment. ‘Mum and Dad provided us with the research about what trees work for the environment, production and management; all the different species, their ease of establishment and how they perform; the best topography for planting various species; engineered woodlands – our preferred method of putting trees into

the landscape – and diversified business opportunities in terms of timber and perhaps farm tourism in the future. It's certainly not just a grazing operation anymore.'

'It's like a big lab. We can observe what trees regenerate by themselves – the wattles sucker in the fenced areas but not in the grazed engineered woodlands – what trees fall on fences, what species die early (wattles), the ones that let lush green grass grow beneath them ... There's still green grass in the oldest thinned pine forests long after the frosts have dried off the grass out in the open. The big blocks of pine – anything more than four rows – are hard to muster and are more difficult to thin than narrow bands of timber in the engineered woodlands.'

Michael is comfortable with the equation of trees, livestock and profits. 'We are definitely not losing livestock production due to the trees. The sheep shelter under them all year round during the hottest and coldest days. Having the shelter for sheep off-shears is one of the most direct benefits. The last two years of wet shearing weather has proven that our valuable weaners can easily find shelter without having to muster them into weather sheds or other shelter, with the peace of mind that comes from next to zero losses due to the weather.'

Michael sees benefits from trees in other ways, too. 'We have just had one of the wettest winters in 30 years, and at such times, the creek lands become over-saturated. After a decade of drought, you wonder why tracks go where they do instead of from A to B.

After last winter, you remember why they pick out the higher ground. I can remember how the flats in Long Frog paddock used to turn into a quagmire, but not this past wet season. The trees along the creek lands keep the ground drier due to better infiltration and deep drainage. We didn't have to move stock out due to the wet conditions, unlike other properties with swampy areas in riparian zones.'

Michael is philosophical about the lack of profitable markets for milled timber currently. 'The sawn timber enterprise is on hold. It might take time before the market improves. But having the resource standing there is not costing us money; it's helping the grazing operation. There will come a time when we run with it again. In the meantime, the timber is growing and we are still pruning and thinning ready for when prices are better. The market for posts, which make up most of our thinnings, is still good and only improves our sawlog trees in the process.'

What have Jon and Vicki left the next generation to figure out? Michael has a few things on his list. Grazing management is one issue. For Michael, biodiversity means a balanced environment, but he doesn't see the pasture diversity he would like to in some paddocks to provide feed in all seasons and under a wide variety of seasonal conditions. Michael is also thinking about permanent reserves fenced from grazing. Jon's father and Jon and Vicki fenced several areas off, around special tree



The Taylors' superfine Merinos have changed their behaviour completely, since the reforestation of The Hill. According to Jon, they spend most of the day in among the trees now. (Photo: Michael Taylor)



Having 15% of The Hill under densely planted tree cover with a fine wool Merino enterprise pays off under a wide range of weather conditions. (Photo: Michael Taylor)



Jon and Michael Taylor with sawn radiata pine at their on-farm sawmill at The Hill. (Photo courtesy of Michael Taylor)

plantings and newly dug dams for clean water provision. Michael is thinking of fencing out one or two more of the hard-to-manage areas across the farm (e.g. rocky knobs) for ease of management, a seed source of palatable species and as a conservation initiative.

In terms of tree selection, Michael wants to plant more long-lived species, such as oaks, and species that will sustain and regenerate themselves in conjunction with livestock grazing. He is also interested in planting



A dam permanently fenced off to provide clean water for livestock and a habitat refuge for plantings of palatable trees and shrubs.

shrubs and native grasses, perhaps in reserves across the farm. He observes that the wildlife comes with the habitat. ‘That’s what we want: lots of wildlife providing plenty of different forms of natural pest control, creating balance, and using grazing management to encourage competitive perennial pastures that also suppress the thistles and other weeds.’ Thanks to his parents, the current and future generations of Taylors have a wonderful legacy to work with.

Native farm forestry – Coombell

Libby and Rob Dyason have lived at Coombell, near Casino, NSW, since they took on the 1475-ha farm from Rob's parents in 1975. The downturn in beef prices on top of the oil crisis and rampant inflation in the early 1970s quickly convinced them to turn their back on conventional agriculture and look for more promising and profitable options. They discovered that the native vegetation on their property had all the answers they needed: oil from the naturally occurring stands of tea tree on flood-prone flats, and top-grade hardwood timber from the spotted gum forest that had regrown after most of the farm had been ringbarked and cleared for dairying between the late 1800s and 1930s.

The realisation that the farm's regrowth forests were a potentially profitable timber resource dawned on Rob as he worked with a sleeper cutter to build a set of stockyards. The gentleman suggested the Dyasons sell electricity poles, which were growing in considerable quantity, and the two spent time cutting poles together so that Rob was able to appreciate the value of the forest resource that had not previously been considered.

While this was happening, some inventory work by a forester and Libby and Rob's own observations led

them to realise that continual removal of poles without simultaneous removal of less elite (smaller and malformed) trees was poor practice and would lead to a lower quality forest. They had the option of selling sawlogs to a sawmill, or milling them themselves. The Dyasons opted to do the latter, keeping control over the entire management chain, from growing and silviculture through to harvesting and production of sawn timber.

Libby and Rob use the sawmill they constructed on-farm as a silvicultural tool, taking sick or defective trees to the mill to saw into marketable products while retaining better quality trees for future cutting cycles. They have installed their own system of forest monitoring plots to measure the growth of the timber resource and ensure a sustainable harvest, and have created a part-time business from teaching others about farm forestry. These arrangements continue to this day, although the sawmill operates only part of the time, with all required sawmilling and extension skills represented on-farm.

After Rob's father heard a radio program about a little known product called tea tree oil, bush-harvested from



A forest inventory plot established by Rob and Libby Dyason in the mid-1990s (left) to monitor the timber resource in spotted gum-dominated forest at Coombell, and the same plot in 2012 showing an increase in grass biomass, groundcover and regrowth. (Photo right: Rob Dyason)



The world's first tea tree plantation, planted in 1979, with spotted gum and mixed eucalypt forest in the background at Libby and Rob Dyasons' Coombell Farm Forestry Centre. The plantation is harvested annually and is still productive.

swamps on the North Coast of NSW, Libby and Rob got interested in the plant they knew grew naturally on the poorly drained flats of their farm. After some investigation, the Dyasons planted their first plot of tea tree in 1979 – now the world's oldest producing plantation – and still harvest it annually. It was not until 1990 that their plantation production exceeded their on-farm wild harvest.

Libby and Rob built their first distillery in 1980 and have been rebuilding and expanding it ever since. More sheds have been built recently to house the newest distillery and one to house a steam-powered alternator for standby power (and Rob's collection of steam antiques). Initially, the distillery throughput

was a tonne of leaf per day, yielding up to 10 kg of oil. Present throughput is limited by harvesting speed but can reach 50 tonnes per day and achieve over 400 kg of oil. Contract distilling for other producers is now a substantial part of the Dyasons' business, and in 2003 they distilled in every month of the year.

Over the years, several species other than the local tea tree have been trialled to diversify from a single essential oil enterprise. Marketing and agronomy have been the main constraints, and several species have been discarded for one or both these reasons. Two species other than tea tree remain in the enterprise mix, however. A small cattle herd is also run, more to reduce the fuel load in the forest and to control weeds in the tea tree blocks than for profit.

Libby and Rob have developed arguably the most sustainable commercial farm in Australia. Their two main products, sawn timber and essential oil, are based on the locally occurring, deep-rooted, perennial vegetation, so that the hydrological and nutrient cycles of the native forest and tea tree plantations are balanced, non-acidifying, non-salinising and drought-proof, with modest production even in the severest drought. The tea tree plantations are harvested just above ground level, groundcover is retained and the land surface is more or less flat, so soil erosion is not an issue. All of the nutrient-rich tea tree foliage as well as the ash from the distillation furnaces are spread back on to the tea tree plantations to close the nutrient loop. In the forest, only scattered trees are removed at any one time. The



Libby and Rob Dyason's on-farm sawmill.



timber is felled, debarked and prepared in the forest prior to milling, so the nutrient-rich bark and foliage remain on the forest floor. The logs are sawn on-farm where the residues and offcuts remain.

Very little leaves the farm other than small quantities of high-value product (sawn timber or poles and pure tea tree oil). The chemical composition of these products is hydrogen, oxygen and carbon, which the plants derive entirely from atmospheric carbon dioxide and rain water, so the main marketed products are fully renewable. The energy source for tea tree oil distillation is largely macadamia shells (a waste product from the region's orchards), or offcuts from the sawmill from timber grown on-farm. Timber contains very little nutrient, being mostly lignin and cellulose, so the nutrient cycle of the farm's production is closed or slightly in credit due to the import of biomass energy. Rain water is used in the distillery.

Apart from the small cattle operation, the only less than sustainable aspect of the Dyasons' operation is their dependence on liquid fuels (\$15 000 per year)

and mains electricity, in common with most other commercial farms in the country.

While developing their indigenous farming system at Coombell, Libby and Rob have raised their two children and put them through boarding school and university, and invested much time in the community. Rob has sat on many government committees trying to bring sense to private native forest policy in NSW. He has had a more rewarding time on the executive of the Australian Forest Growers Association and writing opinion and technical pieces for the Association's journal.

Libby and Rob have also done much more than most to protect Australia's unique flora and fauna. Most of their farm (1200 of 1475 ha) is regrowth native forest and is full of threatened flora and fauna, including the slaty red gum (vulnerable nationally and in NSW), yellow-bellied glider, brush-tailed phascogale and masked owl (all vulnerable in NSW). Special management provisions for these threatened species are incorporated in the property vegetation plan and forest management and harvesting plans that govern



Harvesting a tea tree plantation with a modified forage harvester. The foliage is collected directly in a distillation tank on the back of the truck to save double handling at the on-farm distillery. (Photo courtesy of Libby and Rob Dyason)



Rob in the Dyasons' home-built tea tree oil distillery, explaining the intricacies of private native forest policy in NSW to university students.

operational forestry activities. Informal surveys of birds (107 species) and mammals have been conducted, but the much larger task of flora, reptile and amphibian surveys is yet to be confronted in a coherent way.

Libby and Rob are proud of their sustainable farm and community contributions, but they haven't necessarily found it all easy going. Prospectus-driven, tax-funded, 'get-rich-quick' schemes saw massive over-production of tea tree oil and a price collapse in the late 1990s. However, the Dyasons' control of the entire production and on-farm processing chain coupled with minimal inputs and overheads meant that they remained solvent where others failed. Private native forest policy in NSW has also been vexing, with successive state governments almost completely shutting down native forestry on private land as a sop to the greens. This makes Libby



A fine specimen of slaty red gum in a paddock at Coombell Farm Forestry Centre. (Photo courtesy of Libby and Rob Dyason)

and Rob see red, given their experience of the numerous advantages of commercial private native forestry in comparison to the quality of stewardship of the state-managed alternative. Despite such vexations, Libby and Rob continue to chip away at the bureaucracy in the hope that Australian primary production will one day have better governance.

Farm forestry – Woodside

The management of New Zealand's indigenous forests has been hugely contentious over the last half century with central government prohibiting any timber extraction from public forests and enacting legislation to restrict the nature and extent of harvesting from private forest.³³³ However, for innovative farm foresters like John and Rosalie Wardle, indigenous forestry can provide the opportunity to produce a high value product while also enhancing the diverse range of biodiversity values present. Still they did have one big advantage in that John was a trained forester and had spent the previous 25 years working as a scientist for the New Zealand Forest Research Institute, culminating in his writing the definitive textbook on the New Zealand beeches.³³⁴

The Wardles purchased Woodside (121 ha) on the lower slopes of Mt Oxford in the eastern South Island under Rosalie's name as government employees of that day were not allowed to have a second income source. The property had had a chequered history – the big trees (rimu, kahikatea, matai and black beech) were logged in the 1880s and subsequent fires destroyed most of the remaining forest. Farming occurred through until the depression of the 1930s when the then owners walked off the land. Although used as a summer grazing block

since, the beech forest regenerated as it was uneconomic to improve the pasture and when the Wardles purchased the property in 1973 it comprised 70 ha of regenerating black beech forest, with the remainder in rough pasture and gorse.

John and Rosalie's goal in purchasing Woodside was to turn it into an economically viable forestry operation that also enhanced the native biodiversity values present. Over the first 10 years they established 29 ha of exotic plantation forest in pasture and gorse, mainly radiata pine but also coast redwood, Douglas fir and European larch, and started to manage the beech forest for a sustainable supply of timber. At the same time they removed most of the grazing allowing the beech forest to continue to expand so that it now covers 84 ha of the property. The remaining 8 ha is a mix of pasture and facilities. The beech forest on the property was the first private native forest in New Zealand to have a Sustainable Management Plan approved under the 1993 amendments to the *Forests Act 1949*, while the whole property is now covenanted with the QEII National Trust. This allows for sustainable harvesting, but prevents clear-felling and property subdivision, thus ensuring that the forest will continue for the foreseeable future.

Woodside presents many challenges for management. Although it receives reliable rainfall (1100–1200 mm), the elevation (390–620 m a.s.l.) means regular winter snowfalls while winds coming down from the mountains can be gale-force at times – both the snow and wind can seriously damage forests. Furthermore Woodside is bounded on one side by forested public conservation land, with regenerating beech forest and rough pasture on private land forming the remaining boundaries. While buffering Woodside's forests, these adjacent forests also represent a source of pest species (deer, possums, mustelids, wasps) that continue to reinvade after control at Woodside and impact biodiversity values on the property.

The approach taken to managing both the native beech forest and the exotic plantation has converged



John Wardle with drying black beech timber from the sustainably managed beech forest on Woodside.



Thinned black beech forest.

over the nearly 40 years that the Wardles have owned Woodside, with both forest types now managed using a continuous canopy selection system, where canopy trees are progressively thinned (harvested) to promote regeneration. Harvesting focuses on removing single trees, or groups of two or three trees, with the aim being to provide better protection against wind damage for the remaining trees through promoting increased root growth, and providing protection against winter desiccation and ‘sunburn’ for regeneration by retaining canopy cover. Their focus is on producing high quality logs. Radiata butt logs command a good price because of their clear wood while the remaining timber makes high quality sawlogs. The black beech logs are milled on the property and sold mainly for flooring as well as other uses such as furniture and panelling, which takes advantage of the prominent colour and grain variation in this timber. Ideally, radiata trees will be 60 cm diameter and beech 45 cm diameter at harvest, requiring 26–50 years for radiata and 40–70 years for beech to reach this size.



Young black beech starting to overtop a manuka nurse crop.

Neither forest type is yet fully converted to the continuous canopy selection system as the plantation was established in large even-aged compartments and much of the beech is also even-aged reflecting its relatively recent regeneration. Variations in growth rates in different topographical positions and wind-throw is assisting in shifting the forest to the mixed-age structure required for continuous canopy selection. The primary management intervention in beech forest is the clearing of a 1-m-radius circle around target trees, while both radiata and beech are pruned to provide clear butt logs. Harvesting is ground based with machinery utilising the same tracks each time to reduce soil compaction, with logs winched to tracks as required. While natural regeneration is abundant in beech forests, some planting is required to ensure there is adequate regeneration in the radiata and other exotic species stands. John is slowly diversifying the exotic forest, especially with Leyland cypress, which is slower growing than radiata but less likely to blow over and has better wood qualities. Black beech is also invading some area of radiata pine further diversifying these stands.

Animal pest control is a big part of forest management – John and Rosalie believe that you cannot manage the timber yield from the forest without also controlling the many invasive species that threaten biodiversity. Deer are kept at bay by a number of visiting hunters and provide a regular supply of venison for the Wardles' freezer. Possums are controlled through the use of cyanide, while stoats are trapped. However, the biggest predators are wasps – John has developed an efficient method for their control that involves poisoning a few nests each year and then leaving the foraging wasps to carry the poison to other nests, thus reducing this ubiquitous pest to very low numbers. Dog flea powder has proved ideal for doing this as fibronil, one of the active ingredients, is very effective against wasps. The result of all their hard pest-control work has been an



Even-aged radiata pine forest now being managed under a continuous cover selection system.

upsurge in native birds on the property, especially bellbirds and smaller birds like fantails, tomtits and grey warblers.

A simple philosophy underlies the management approach John and Rosalie have applied to both the exotic and native forest and can be summarised by two quotes from a century apart: 'Trust not authority, pay no heed to the books, but go to the plants themselves' (R Brown 1910). 'What you take from the forest, you must put back' (John Wardle 2010).

Diversified farming – Bangor

Bangor is a 6400-ha property on the Forestier Peninsula in south-eastern Tasmania, near Port Arthur.³³⁵ Bangor has been in the Dunbabin family since the 1890s and Tom Dunbabin and Matt and Vanessa Dunbabin are the fifth and sixth generations, respectively, to have managed this stunning property.

With 35 km of coastline and 5100 ha of native forests, woodlands, grasslands and wetlands, Bangor is habitat for several threatened species or subspecies, including the Tasmanian devil, wedge-tailed eagle, swift parrot and white-bellied sea-eagle. Coastline, wetlands and several significant vegetation types are conserved, including grassy forests of Tasmanian blue gum and black gum (breeding habitat of the nationally endangered swift parrot). Native vegetation across the property also includes wet and dry sclerophyll forests of stringybark, white and brown peppermint, white gum and sheoak along the coast.

Bangor features significantly in Tasmanian history, the Dutch landing there in 1642, and Aborigines and

Europeans making first contact on its shores in 1772. The Dunbabins are proud of Bangor's natural and cultural heritage, and nurturing and sustaining that legacy is a core management philosophy.

Bangor was first developed as a farm to feed the Port Arthur penal settlement in the 1830s. Today, the Dunbabins manage an extensive grazing operation, featuring a superfine Merino stud and wool flock, and prime beef and prime lamb enterprises. The flock of 5000 superfine Merino sheep run on extensive native and bush pastures, providing even nutrition year round. The 16.5-µm wool is sold into the top end of the market for premium suiting, next-to-skin wear and outdoor clothing. Bangor also runs a 250-head beef herd and a 1500-head prime lamb flock on sown pastures. The meat is sold into both domestic and export markets.

With a view to the future, Matt and Vanessa have been developing new enterprises at Bangor. A 3-ha vineyard has been established that will produce premium cool climate wine to be marketed under the property's own



Aerial view of the Bangor coastline. (Photo: Matt Dunbabin)



The Tasmanian subspecies of the wedge-tailed eagle is listed as endangered under the Tasmanian *Threatened Species Protection Act 1995*. (Photo: Matt Dunbabin)

label. As well, a 1500-ML dam is under construction, providing a water resource that will be both reliable and economical. This will allow the transformation of parts of the farm from dryland grazing to high-value irrigated crops and pastures. This approach forms part of a strategy to increase production and profit from the cleared parts of the property, allowing the remainder of Bangor to continue to be managed for its conservation values.



Pinot noir vines in the recently established vineyard. (Photo: Matt Dunbabin)

The Dunbabins used to run a native timber enterprise, based on partial logging of some of their forest estate. However, according to Tom, ‘we could see the writing on the wall a few years ago and established 300 hectares of eucalypt plantation. It is ironic that the politics of forestry have led to the abandonment of the sustainable use of native forests to very unsustainable plantations! I suspect it will be some time before there is a market for native forest timber again, if ever’.

The Dunbabins have been committed to landscape conservation for many years, evident not only in the sustainable agricultural practices employed on their farmland but also in their strategic permanent protection of important natural habitats across Bangor through the establishment of conservation covenants that contribute to the National Reserve System. ‘We have reserved some 2000 hectares, much of it under formal protection in perpetuity,’ explains Tom. ‘We have targeted the areas of greatest diversity and corridors of natural habitat that link up across the peninsula to form a significant area for wildlife protection.’ The family also runs superfine wool Merinos on their 2000-ha property, ‘The Quoin,’ near Ross in the Tasmanian Midlands. This property is almost entirely native forest and native pasture, and relatively undeveloped apart from some clearing of timber in earlier times. There are several threatened plant species in the grazed pastures, and the conservation of some of these species seems dependent on sheep grazing. They include fuzzy New Holland daisy, sheathing yellow star and yellow riceflower.

The Dunbabins encourage environmental research at Bangor and The Quoin. Researchers from the ‘Save the Tasmanian Devil Program’ are currently conducting a long-term devil trapping program across Forestier Peninsula, with many sites on Bangor, in an effort to monitor and understand the spread of Devil Facial Tumour Disease and find solutions before it is too late.

The Private Land Conservation Program of the Tasmanian Department of Primary Industries, Parks, Water and Environment has monitored a grazing exclosure trial in the Bangor Private Forest Reserve since 2002 to examine the effects of grazing on grassy Tasmanian blue gum forest. The study aims to determine if grazing management can maintain plant species diversity and vegetation structure, and allow



The Quoin in the Tasmanian Midlands. (Photo: Tom Dunbabin)

the regeneration of eucalypt and shrub species. It also aims to investigate the relative impacts of stock grazing and native browsers on these attributes. Some 114 vascular plant species have been recorded in 312 quadrats on seven sampling occasions between 2002 and 2010, including 87 native perennials. The number of species in plots with complete exclusion of grazing has declined significantly over time. In general, grazed plots and sheep-excluded plots do not vary, suggesting that native grazers effect most vegetation change.

Professor Jamie Kirkpatrick and Dr Kerry Bridle of the University of Tasmania conducted grazing research on the native pastures at The Quoin over the past decade and maintain long-term monitoring sites there. ‘Tom wanted



A Tasmanian devil at Bangor – part of the trapping project for the Save the Tasmanian Devil Program. (Photo: Matt Dunbabin)

to know how much pasture production native animals accounted for,’ recalls Kerry. ‘We had 10 paired plots at two locations in one run [paddock]. Each pair consisted of a fenced and an unfenced plot, the latter open to all grazing animals all the time. When the sheep were in the run, the cages were lifted for the sheep to graze everything. When the sheep were removed, the cages were lowered. Just before the sheep were due back in, we remeasured everything. Any difference between the fenced and unfenced plots was the offtake of the marsupial grazers. Basically macropods were the main native herbivore and accounted for more than 40% of pasture biomass removal, roughly equating to one dry sheep equivalent per hectare, the same as the sheep stocking rate.’



The hoary sunray (left), a nationally endangered paper daisy, and the prostrate bush-pea, listed as vulnerable in Tasmania. Hoary sunray occurs in grassland, woodland and forest. Since it is unpalatable to sheep and bare ground is required for germination, it does well in grazed native pastures where heavy grazing creates patches of bare ground, favouring recruitment.³³⁶ The prostrate bush-pea also withstands heavy browsing.³³⁷ (Photos courtesy of Matt Appleby, Kerry Bridle and Louise Gilfedder)

Tom was the driver of a native pasture condition poster that came out of a national research program, Land, Water & Wool (LWW), of which the studies at The Quoin were a part, as well as a scat fact sheet to help Tasmanian sheep graziers better understand total grazing pressure on their runs. 'We counted over 53 plant species in a 5×5-m grassy woodland plot at The Quoin – the highest of any of the 150 sites in the LWW project,' Kerry recalls. 'The Dunbabin have supported lots of research on their properties. They understand the value of biodiversity and conservation management as part of their farm businesses, and they take great pride in their environmental achievements.' In addition to the native pasture and devil research, research and monitoring projects conducted or continuing at Bangor or The Quoin include shrub invasion and grazing impacts in wetlands, and monitoring of forest exclosures.

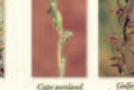
Others agree with Kerry's assessment of the Dunbabin record of combining agricultural production and environmental management. The family has been recognised nationally with a national landcare award for

nature conservation in 1996 and the McKell Medal for excellence and achievement in natural resource management in 2004. These are highly prestigious awards for outstanding contributions to land and water management in Australia. The agricultural industries have also benefited from the family's commitment to wider society, Tom having served on various local, regional, state and national committees for over 20 years. Most recently, he chaired Australian Wool Innovation's sustainable wool advisory group for several years.

Australia's biodiversity is in good hands at Bangor and The Quoin, given the commitment and passion of the Dunbabin family. Matt and Vanessa know that Bangor is a great place for their young family to grow up on, and they would like their children to have the same opportunity to live and work there. Profitable agricultural enterprises are the key to ensuring that the integrity of this large area of land can be maintained, allowing its biodiversity values to be looked after for generations to come. A challenge for agriculture is to foster a similar level of environmental stewardship and achievement across the sector.

Using indicator species as a guide for managing Tasmanian native pastures

If your paddock is dominated by native grasses, how many of these species do you have?

Shrubs	Daisies	Lilies	Orchids
 Native cranberry	 Common everlasting	 Tasmanian lily	 Common golden orchid
 Dwarf trifoliate	 100-day	 Early nancy	 Black to gold orchid
 Silly indigo*	 Charming heather	 Belted lily	 Cape pond orchid
 Harry guineaflower	 Climax daisy*	 Goulden lily	 Golden bell orchid*
 Peachery bush	 Milly houseplant*	 Sheep's yarrow	 Broad new orchid

* Rare or threatened species

4 or more, with spaces between tussocks and mosses and lichens on soil surface	2-3, with spaces between tussocks and mosses and lichens on soil surface	1, with few spaces between grass and tussocks	1, with bare ground and some weed species	0, with large bare patches and/or patches of weeds
A+	A	B	C	D
Paddock condition:	Paddock condition:	Paddock condition:	Paddock condition:	Paddock condition:
Management has maintained biodiversity values - do not change unless absolutely necessary, and without considering impacts on vegetation	Management generally consistent with maintaining biodiversity values. Resting in spring-summer will promote native species	Build up of rank grasses has excluded native species. Grazing or burning in late summer-autumn will promote native species	Disturbance creating bare ground and facilitating weed invasion. Reduce grazing pressure, particularly in spring-summer	Management not consistent with maintaining biodiversity values. Reduce stocking rate and/or rest paddock, particularly in spring-summer

Also look out for rare or threatened species

 Goulden lily	 Shade poppy*
 Goulden lily	 Clear daisy*
 Harlequin new orchid*	 Tallied lily*

Notes on using this guide
Use this guide to determine how well you're managing biodiversity values in your native pastures. Examples of Tasmanian native pastures are shown in the pictures above.
Spring/early summer, when plants are in flower, is the best time to carry out this assessment. It's best to go out in the sunny areas, they may remove flower heads, making plants harder to spot and identify. Note that the records are a very diverse group, so the plants are spread across your area may differ from those shown.
The management recommendations are based on government guidelines for native grassy vegetation. Appropriate management for a particular site depends on the species present and site characteristics. Further information on management can be obtained from 'Managing Tasmanian Native Pastures'. A technical guide for graziers, written by Neil McKee and others (2006). This publication can be downloaded from <http://www.landwaterwool.gov.au/>

Examples of rare or threatened species
are shown above and at left (indicated by *). Some of these species are found in good quality native pastures while others occur in a range of pasture conditions.
A general rule for maintaining these species is, if the population is stable, to maintain current management. For more detailed advice on managing rare or threatened species contact the Threatened Species Section, Department of Primary Industries and Water.

Land Water & Wool logo, UTAS logo, Tasmanian Government logo, Department of Primary Industries and Water logo, Australian Wool Innovation logo

Tom was instrumental in encouraging Dr Kerry Bridle and colleagues at the University of Tasmania to produce this Land, Water & Wool poster showing how Tasmanian graziers can manage the biodiversity values of native pastures. (©Australian Wool Innovation and the University of Tasmania)

11

OPPORTUNITIES AND CONSTRAINTS

Conservationists have often perceived agricultural landscapes to be hostile to native biodiversity because of farmers' focus on food and fibre production, the dominance of agricultural plants and livestock, and some of the attitudes in farming communities. Notwithstanding the challenges posed by agricultural landscapes, they also offer opportunities for biodiversity conservation that do not occur in national parks and equivalent reserves. In this chapter, we explore the opportunities and constraints for sustaining native biodiversity in agricultural environments. An appreciation of these issues is important if we are to maximise the long-term utility of agricultural landscapes for native biodiversity conservation and management.

Opportunities

Compared to many protected areas that are remote, rugged and difficult to access, agricultural landscapes

typically have easy access and good infrastructure that facilitate biodiversity management. Farmers are common on the ground compared to park rangers, are present 24/7 (without the overheads associated with government agencies), are practical and innovative resource managers used to striving for efficiency, and the world expert on their farm.³³⁸ While farmers may not be biodiversity experts, they often have a good knowledge of the local common species (although not necessarily their formal or scientific names). Overall, they are also aware of seasonal and longer-term changes and the factors that affect native biodiversity. Many have a strong stewardship ethic for their land, water and biodiversity assets, and with a little information farmers sometimes go to considerable lengths to protect and conserve their property's natural resources and unusual native plants and animals. All of these attributes offer substantial opportunities for biodiversity conservation.



Graziers Caroline and James Street have undertaken a wide range of soil, water and biodiversity conservation projects on their 830-ha farm, Blaxland, near Walcha, NSW.

Like others, most farmers love to talk. When farm duties allow, they are keen to discuss various management options and are often prepared to try another approach if the justification is clear and the alternative practical and sensible. Modern farmers are by nature innovators as is clear from their ability to adapt to the changing socio-economic and environmental conditions with which they are continually faced. Their ability to innovate is also clear from the many exciting biodiversity initiatives that have already been implemented across rural Australia and New Zealand (examples of which were described in the previous chapters of this book). A challenge for conservationists is to acknowledge farmers' expertise and willingness to engage, and to work with them.

Agricultural landscapes present opportunities to use primary production technology to enhance or safeguard biodiversity, especially for establishing restoration plantings. Ploughs can be used to disturb the thick thatch and seed-laden topsoil associated with pastures, allowing seedlings of native woody species to

establish and grow in farmland.³³⁹ Pasture establishment equipment (drills, seeders and harrows) is used to establish Mitchell grass in coolibah–black box open woodland in semi-arid Australia. In the Sacramento Valley of California, flood irrigation associated with abandoned rice fields has been used to facilitate the establishment of woodland restoration plantings. It is also easier and less complicated bureaucratically to use large earthmoving machinery to build engineered wetlands or to return rivers to their historical beds in agricultural landscapes than in protected areas. Agricultural plants and animals can also enhance biodiversity values. Examples include the use of exotic trees as seasonal food resources for native fauna (e.g. the use of spring foliage on willows or tree lucerne by kereru in New Zealand), to improve connectivity (e.g. radiata pine plantings as avian corridors and habitat for declining woodland birds like rufous whistlers),³⁴⁰ and the use of grazing animals to manage invasive species (e.g. sheep browsing to control wilding pines and sweet briar in New Zealand).³⁴¹



Farmers discussing organic sheep and beef farming at a field day, North Canterbury.



Ploughing of an exotic grass sward in preparation for sowing the seed of native woody species, North Canterbury. (Photo: Nick Ledgard)

Farm businesses can also present opportunities for native biodiversity not available in protected areas. The willingness of European consumers to buy products that meet 'green' certification standards means that there can be market advantage for farmers to manage for biodiversity. For example, New Zealand Merino farmers selling their wool through the New Zealand Merino Company to high-value clothing manufacturers such as Ice Breaker, SmartWool, Howies and John Smedley must meet the requirements of the Zque certification scheme. In turn, these clothing companies use green environmental images associated with the New Zealand high country to market their products internationally.

The accessibility of farmland also makes it attractive to community groups keen to be involved in conservation initiatives. Farmland is often closer to urban centres and easier to access than national parks and wilderness areas. Since manipulation and experimentation on farmland is not limited legislatively in the same way as it is in protected areas, agricultural landscapes can be more suitable for the involvement of educational groups and for conducting some kinds of research in biodiversity management than national parks and equivalent



Marketing of Merino clothing in the United Kingdom, based on the 'green' image of New Zealand high country Merino farming systems, helps to promote biodiversity management on farms. (Image supplied by New Zealand Merino Company)

reserves. Agricultural landscapes are often the 'wildest' landscapes with which most city dwellers ever come into contact. For many urban people in Auckland or Brisbane, for example, their experience of 'wild' or 'natural' places will be the agricultural landscapes they drive through on the way to a favourite holiday location, beach or picnic site. Biodiversity conservation initiatives in rural areas may therefore be able to achieve strong conservation advocacy outcomes as well.



Farmland is a great place for farmers and the community to learn about ecological and sustainable land and water management principles.

Challenges

The nature of agricultural landscapes, especially the effects of fragmentation, the economic realities of farm management, the lack of scientific understanding of biodiversity issues, the attitudes of some farmers towards biodiversity conservation, and the lack of public support for conservation initiatives in farmland all pose challenges that need to be addressed in moving towards a new paradigm for sustaining native biodiversity in rural areas. Habitat fragmentation, local extinctions, the impacts of invasive species and the historical legacies of past management practices (e.g. irreversible degradation) are key issues. Although some of these factors influence native biodiversity in protected areas, their effects are amplified in agricultural landscapes. For example, the compaction of soils in grazed salmon gum woodlands in Western Australia has resulted in long-term changes in soil hydrology, with less water infiltrating into soils. Mature salmon gums are slowly dying in many remnants, even protected ones, while it is difficult to establish new plants without soil modification to enhance water infiltration.

The realities of running a farm business mean that biodiversity conservation often has to take a back seat compared to other aspects of farm management, especially when economic conditions are tough. This together with the tendency to increase production and the intensity of farm management when margins are squeezed leaves little time and resources to invest in conservation activities unless managers are committed. Agricultural landscapes are subject to ongoing impacts

arising from farming activities. It is not always possible to ‘switch off’ activities such as fertiliser input or irrigation, or their effects on native biodiversity in or adjacent to farmland. Equally, it is not always possible to maintain biodiversity management (e.g. the control of an invasive species) when times are tough, yet the cessation of such work could see desired conservation outcomes set back many years. Furthermore, given native vegetation and endangered species regulatory controls and the lack of financial incentives to conserve native biodiversity, some may actively eliminate native plants and animals in order to preempt possible opportunity costs down the track.

Biodiversity conservation is hampered by a poor understanding of historic and current native biodiversity in rural landscapes. We are ignorant of the past and present abundance of native plants and animals in most farming districts. For example, we often do not know if the current rarity of a particular plant or animal represents the result of a steady decline through time or if the species might only have recently arrived and be slowly increasing. We also know very little about the dynamics of invasive species – for example, are we seeing turnover in weed species through time, as has been suggested for weed communities in Central Otago,³⁴² or is a weed species once established always present? There is poor understanding of the impacts of farm management on native biodiversity and limited knowledge of the options for restoration of biodiversity in farmland. Much of the research on biodiversity in agricultural landscapes has been reserve-oriented,



Heavily grazed salmon gum woodland with little understorey or ground vegetation and heavily compacted soils.



Forest clearance for dairy farming, Westland – realising an economic potential before regulation might restrict the activity.



A 30-year research trial in the Mackenzie Basin that is providing information on the effects of a range of management inputs (fertiliser, over-sowing, stocking) on both economic and biodiversity values.

either focusing on what is happening in remnants or on the effects on native biodiversity of totally excluding agricultural activities such as grazing. Far less is known about the effects of different types, intensities and timing of agricultural practices (e.g. planned vs conventional grazing), or the factors controlling the population dynamics of native species in farmland (e.g. the spatial distribution of breeding sites and seasonal food resources of birds). These knowledge gaps mean that, in many instances, management recommendations are educated guesses based on first principles only.

Farmer and societal values and awareness are barriers to biodiversity conservation in agricultural landscapes. The recency of society's appreciation of the importance of native biodiversity and a lack of awareness of biodiversity outside protected areas presents a challenge

in gaining support for rural conservation. It has been argued that the Judaeo-Christian divine instruction '... be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth ...' is ingrained in many farmers' values, shaping attitudes and influencing actions. Certainly, the belief is often expressed that it is waste to 'lock up' potentially productive farmland for nature conservation, or worse if such areas harbour weeds and animal pests or pose a fire hazard. The urban population's lack of awareness about rural matters does not help. It would be a good thing if there were more, warm and fuzzy natural history television programs filmed in farmland! Finally, poor public policy relating to resources, agriculture and finance can result in perverse outcomes for native biodiversity in farming regions. For example in New Zealand, the push by government agencies and non-government groups for tenure review on extensive pastoral lease properties in the eastern South Island has resulted in substantial freeholding of the lower altitude parts of these properties, while the more rugged and remote mountainous areas have gone to the public conservation estate. Subsequently, some farmers have implemented intensive cultivation and irrigation schemes on newly freeholded lands, with the potential for biodiversity loss, hydrological changes and nutrient leaching from these areas, and associated downstream effects.

A final challenge relates to uncertainty around the guarantee of positive biodiversity outcomes in agricultural landscapes in the long term. For instance,



The results of an experiment comparing planned grazing (left) versus continuous grazing in New England native pastures on coarse granite soils. (Photos: Christine Jones)



Land tenure review means that lower altitude areas on high country farms can be developed as irrigated pastures and crops, Mackenzie Basin.

if a landowner who has achieved positive conservation outcomes on their property over a lifetime eventually sells to someone with no interest in sustaining native biodiversity, many of the positive initiatives may be undone. This situation could actually result in a net loss for native biodiversity in the case where the original owner had made trade-offs between conservation and development (e.g. protecting one area in order to offset the development of another area), if the new owner then clears the remaining areas with native biodiversity values (i.e. a net loss in biodiversity).

Conclusions

While many factors work against the conservation of native biodiversity in agricultural landscapes, none of these constraints are insurmountable. Clear recognition of the private property rights of rural landowners together with engagement, advice and the introduction of incentives to manage for native biodiversity can address many of these constraints and are discussed in the next chapter. Recognition of these barriers is essential to ensure that goal setting and management planning for native biodiversity are realistic and achievable in rural landscapes (discussed further in Chapter 13). Agricultural landscapes offer many opportunities for sustaining biodiversity. Given that the only place that many native plant and



Having everyone – farmers, scientists and agency staff – learning together and working for positive biodiversity outcomes in farmland is a win-win. (Photo: Leah MacKinnon)



This 'Westonfence' is an example of farmer innovation. Peter Weston developed his fence to control total grazing pressure (including kangaroos and goats) in western NSW rangeland. He and his sons manufacture the polyethylene fence droppers and fastening spring steel clips at home at 'Yalgo', Nymagee, NSW.

animal species and biological communities occur in rural landscapes, there is an imperative to seize these opportunities or witness further extinctions. Farmers are often in the best position to manage and conserve native biodiversity outside formal protected areas and commercial forests. The challenge is for scientists, agency staff and the general public to work with rural communities to achieve sustainable biodiversity conservation outcomes in agricultural landscapes.

12

FACILITATING BIODIVERSITY CONSERVATION

In order to sustain native biodiversity in agricultural landscapes, mechanisms are required to help farmers manage native species as part of routine farm management. In some cases, all that is needed is to encourage the farmer's existing management approach. Sometimes, however, mechanisms are required to assist farmers change their management or adopt new practices that are more sympathetic to native biodiversity. In implementing such mechanisms, often referred to as incentives, the private property rights that a landowner enjoys need to be respected. Incentives should also recognise the degree to which biodiversity management results in 'public good' outcomes as opposed to 'private gain', although the distinction between these is not always clear. Various mechanisms are available and are usually summarised in three broad categories: regulation, financial or market incentives, and voluntary incentives. In this chapter, we explore these different mechanisms and the opportunities they provide for sustaining native biodiversity in rural landscapes. First, we discuss the issues of private property rights and public good, as these are fundamental to understanding how incentives and other mechanisms work.

Private property rights and public good

Landowners have a set of property rights associated with their ownership of land titles embodied in the legal structures that underlie governance and society in Australia and New Zealand. These property rights include the freehold rights of landowners to use their property for economic gain and the right to restrict public access on to and across their property. Private property rights in Australia and New Zealand are derived partly from the legal system inherited through our colonial history with

England and partly from the desire of those settling New Zealand and Australia to break away from the stringent controls that existed over people's rights in England in the 18th and 19th centuries.

Property rights are central to a discussion of incentives for native biodiversity as such instruments aim to directly or indirectly alter property rights in favour of native biodiversity. The challenge is to do this in a manner that doesn't alienate the owner of those property rights. If property rights are clearly recognised and respected, then people with different values and priorities can come together to negotiate an outcome satisfactory to all. However, if property rights are not recognised or respected, one group may attempt to reallocate these rights via the political process, thus alienating the other party. Most New Zealand farmers saw the unsuccessful attempt by the Clark Labour government in the early 2000s to open up public access across farmland in this light. The challenge for biodiversity conservation in



Public access can be a point of tension in many farming communities. (Photo: the late Rodney Patterson)

agricultural landscapes is to ensure that farmers' property rights are recognised, and where proposed changes to management compromise these rights, appropriate measures need to be instituted to ensure that farmers are compensated for their loss. Otherwise, it will be difficult to engage the farming sector to consider broadly based mechanisms to sustain native biodiversity across rural Australia and New Zealand.

Related to the issue of property rights is the issue of who bears the cost of biodiversity conservation. Sustaining native biodiversity in agricultural landscapes can have multiple benefits, some of which accrue to the farmer through the provision of ecosystem services (e.g. pollination, natural pest control, shade and shelter provision, soil erosion mitigation) or where the biodiversity is a direct source of income (e.g. through grazing native pastures or managing native trees for timber). However, many, and perhaps most, of the benefits that arise from sustaining native biodiversity on farmland are public good in nature, including the provision of a range of ecosystem services. Examples include clean water, flood damage mitigation and storm protection, wildlife habitat, educational and ecotourism



A thickly vegetated riparian zone along a backwater near Moree. Well managed riparian zones provide habitat for biodiversity and protect streambanks from erosion, as well as leading to clean water supplies for downstream users – for farmers, recreationists and urban centres alike.

values, to name but a few. Other public good outcomes are the intrinsic values of the native species themselves, and the values that biodiversity convey to society at large in terms of sense of place, local or national identity and pride (e.g. koalas utilising farm trees or kereru [wood pigeon] feeding in farm orchards). Given this, the question needs to be asked: who should bear the costs? Jamie Kirkpatrick and Kelly Bridle posed this question with reference to Tasmanian Merino farmers and suggested:³⁴³

Graziers distrust the ability of government to understand the exigency of their operations, and fear that they will be forced to subsidise the conservation costs of society in general. Realistic payment for conservation services combined with sympathetic regulation appears to be a feasible solution.

On the other hand, conservationists distrust some farmers' concept of sustainability, arguing that there is more to on-farm biodiversity conservation than soil conservation and efficient use of rainfall and inputs. The challenge for biodiversity conservation is to develop incentives that recognise private property rights and the relative costs and benefits of conservation in a manner that leads to better management and sustains native plants and animals in rural landscapes.

In selecting the most appropriate approach for influencing farmer behaviour in favour of biodiversity conservation, it is important to consider the relative levels of public (external) and private (internal) benefits of a given land management practice.³⁴⁴ Depending on the relative levels of these benefits, different approaches are likely to be most appropriate. For example, where public benefits are high and private benefits are close to zero, then regulatory tools that encourage change (e.g. grants) may well be the most beneficial, although if private benefits are moderate, then market or voluntary incentives might be more appropriate. However, when there are likely to be negative public benefits (i.e. loss of public-good values) and only limited private benefits, then regulatory tools that restrict an activity (e.g. rules) are likely to be most beneficial. What is important is that when considering the most appropriate approach for facilitating land management that supports native biodiversity, policy makers should consider the levels of both public and private benefit involved.

We now consider the different types of mechanisms or incentives that are available to assist landowners and managers in sustaining native biodiversity in rural areas.

Regulation

Regulatory controls or restrictions on environmentally damaging activities are formalised in legislation or the planning tools of governments and government agencies. This approach is often referred to as ‘command and control’. Landowners who ignore these controls and regulations can be subject to legal action resulting in fines or in some cases incarceration, although the latter is rare. Regulation is the stick in the ‘carrot and stick’ analogy of environmental policy.

Regulatory tools are based in legislation or planning provisions and, although there are differences among jurisdictions in detail and implementation, their function is essentially similar. In Australia, the states and territories have various parliamentary acts governing the impacts of land management on water, soil and biodiversity. In terms of biodiversity, all states have native vegetation laws or planning provisions that regulate vegetation clearance on freehold land (e.g. the *Native Vegetation Act 2003* in NSW), while federal legislation that identifies and protects endangered ecological communities and species (*Environment Protection and Biodiversity Conservation Act 1999*) is supported by similar statutes in most states. In New Zealand, the *Resource Management Act 1991* requires local and regional councils to develop plans with rules relating to acceptable levels of impact on soil, water and native biodiversity, among other matters, associated with various development activities. As a result, most councils have specific vegetation clearance rules that directly affect farming and forestry activities. New Zealand lacks endangered species legislation, although the *Wildlife Act 1953* restricts impacts on most native vertebrate fauna. The *Conservation Act 1987* gives the Department of Conservation, a central government agency, the ability to advocate for rules relating to native biodiversity on private land under the *Resource Management Act*. In both Australia and New Zealand, landowners in breach of these regulations are liable to prosecution by the responsible government agency or, in the New Zealand case, by local and regional councils.



Clearing of timber in ephemeral wetlands west of Moree. (Photo: Chris Nadolny)



Natural hoop pine–eucalypt forest aerially sprayed with herbicide in breach of NSW vegetation clearance rules in an attempt to control lantana and other weeds in the understorey. (Photo: Chris Nadolny)

While regulations are often blunt instruments lacking flexibility, they provide some certainty of outcome (e.g. a prohibition on broadacre native vegetation clearance) and a line in the sand or starting point from which other policy mechanisms can be developed to suit local conditions or particular activities. Regulation is important to try to ensure that the ‘last example’ of a species or ecosystem is protected. Regulatory approaches may encourage otherwise recalcitrant, incompetent or intransigent landowners to do the right thing, and catch landowners who do not respond to other overtures. On the other hand, new regulation by itself is often viewed as an infringement of property rights and can limit innovation and discourage more efficient ways to achieve desired biodiversity outcomes. Furthermore, if regulations are onerous or restrictive and perversely penalise those with biodiverse properties, which is often the case, they can discourage landowners from pursuing voluntary actions to sustain native biodiversity. Indeed the result of regulation may be the reverse of that intended.

A good example of such unintended outcomes can be found with implementation of the federal *Endangered Species Act 1973* in the United States, which prevents the take of listed species. Take is defined to include habitat removal, and the listing of species under the Act has been a contentious process because of the legislative power it wields. Debates over the management of Pacific north-west forests with northern spotted owls or the interaction between oil extraction and polar bears in Alaska are good examples. The red-cockaded woodpecker, a species of eastern North American longleaf pine forests, is listed under the Act, which prevents forest harvesting when woodpeckers are present. Woodpeckers prefer older pine trees: in North Carolina a strong association has emerged between the average age of tree harvest and woodpecker density.³⁴⁵ Essentially forest owners harvest timber on very short rotations when red-cockaded woodpeckers are in the vicinity to ensure that woodpeckers do not utilise their forests and therefore restrict future harvesting options. This results in the perverse outcome of a reduction in habitat quality for woodpeckers except in sites where they are known to live.

In some cases, farmers faced with regulatory restrictions on land management (e.g. vegetation clearance) may choose to act illegally and accept the fine

as a cost of doing business, assuming they are caught. In these cases, longer term productivity gains presumably outweigh the financial penalty for breaking the rules. This situation highlights the perils for government in relying on poorly designed regulation in isolation from other policy instruments such as incentives. An obvious response to this situation might be to set a variable fine at a level proportionate to the business’s size so that the penalty imposes real economic hardship. Another option is to require the offender to repair the damage and regenerate the vegetation to an acceptable condition,³⁴⁶ a process that could take decades and require considerable expenditure before sign-off. While such measures would further alienate lawbreakers, tough regulation would please farmers who respect the intent if not the detail of the law.



In the time of ornithologist and painter, John James Audubon (1785–1851), the red-cockaded woodpecker was abundant in open pine forests of the south-east USA from Texas to New Jersey, nesting in old trees with diseased hearts.



Sown pasture on a New Zealand farm that was established without regulatory approval in an area that was previously dominated by native species.

Perhaps the most obvious problem with regulation is that it commonly fails to address the infringement of private property rights and the compulsory acquisition of public goods at the expense of those whose rights have been diminished. Another problem with regulation is that if it is poorly drafted or is not enforced, the environment may deteriorate more rapidly and become more degraded than if the statute had not been introduced in the first place. Furthermore, land managers alerted to a government's intentions to introduce new regulations may rush to thwart its intent. For example, a large area of native grasslands in NSW was cleared in a short period after the introduction in August 1995 of *State Environmental Planning Policy 46* (SEPP 46) which imposed a general prohibition on woody vegetation clearance on freehold land, but not grasslands.³⁴⁷ While regulation is an important part of sustaining native biodiversity in agricultural landscapes, especially for highly threatened biota, it is only one approach. It needs to be carefully designed and negotiated to avoid perverse outcomes, socio-economic hardship and upsetting the very constituency that is expected to comply with the new laws. Regulation (as the 'stick') must be complemented with non-regulatory approaches (the 'carrot') that facilitate biodiversity management while respecting private property rights. Alternative approaches are explored in the next two sections.

Financial incentives

Financial incentives are designed to influence a farmer's management through monetary reward, giving the farm manager a choice in accepting a financial benefit in exchange for agreed management outcomes, or simply maintaining the *status quo*. Financial incentives can be grouped into three broad categories:³⁴⁸

- **Price-based incentives** incorporate the external costs or benefits of an action (e.g. a tax on pollution or a subsidy for a particular management action), resulting in individuals changing their behaviour to reduce costs. These incentives often involve setting or modifying prices to reflect the desired outcomes.
- **Quantity-based incentives** involve indirect financial signals that enable trading in rights to undertake polluting activities (e.g. carbon credits), resource extraction (e.g. water licenses) or the provision of compensation in return for not undertaking an environmentally destructive action. Those that are most prepared to trade or accept compensation change their behaviour more than others. Quantity-based incentives involve the regulator setting targets to achieve or maintain particular outcomes (e.g. a total quantity of carbon pollution credits or volume of water that can be extracted from a river or groundwater system).
- **Market-based incentives** enable those prepared to change behaviours to either obtain a greater financial return or more often simply access to a market through market recognition of the behaviour change (e.g. a market premium for organically produced food and fibre). Environmental requirements and restrictions on the entry of products into certain markets are essentially obstacles ('market friction') that primary producers must overcome if they want access to markets or premium prices.

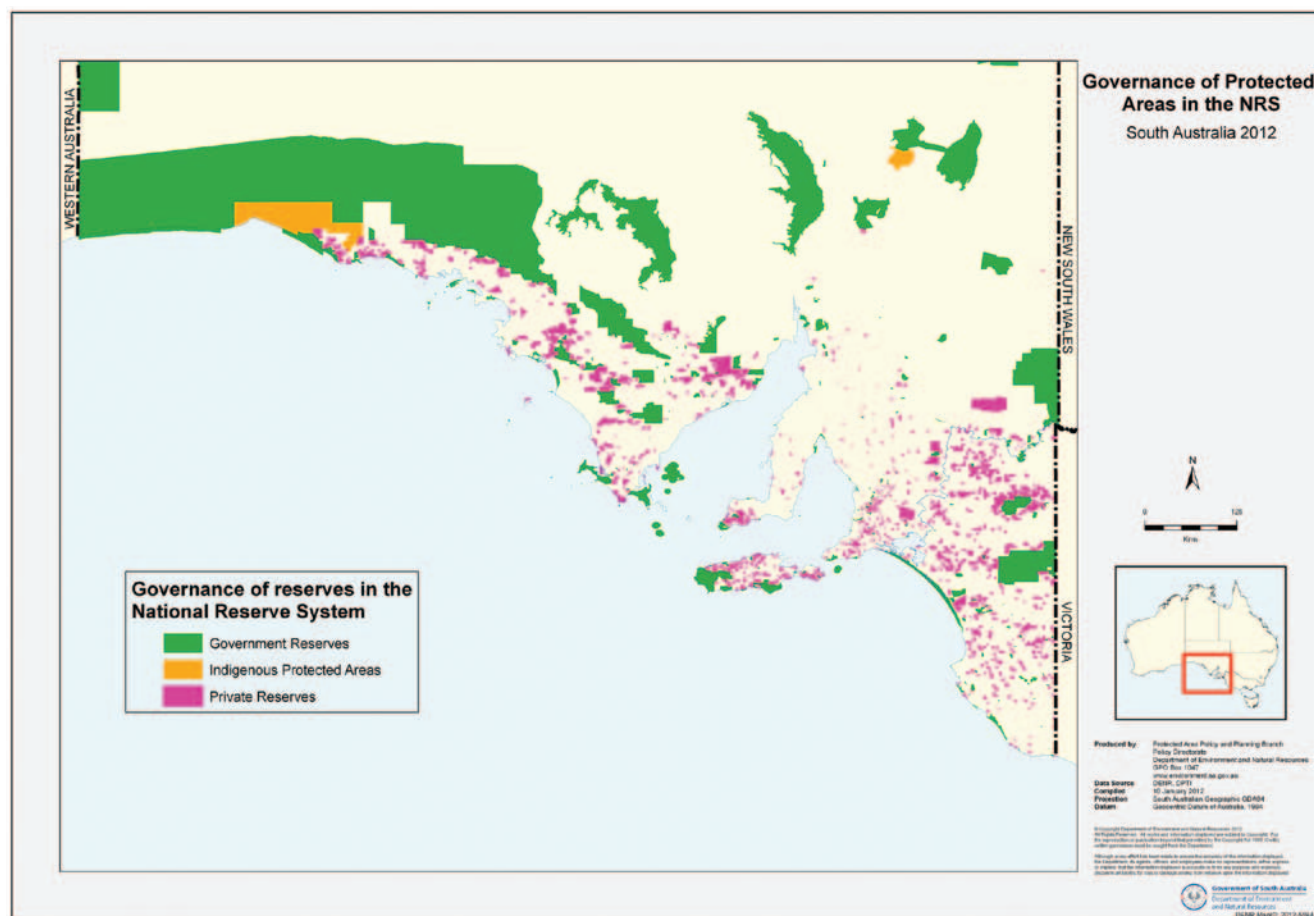
Price-based incentives (e.g. taxes, fees and charges) can be used to try and change behaviour in order to sustain biodiversity, but are also a way to fund public conservation work. The most common way that these are used in agricultural systems is through rebates on rates or taxes. In New Zealand, local authorities provide a rates rebate for farmers who establish a conservation

covenant over part or all of their property. The South Australian government pays a rebate to private property owners equal to the local government rates on native vegetation registered under a heritage agreement, as well as providing financial assistance for fencing and land management. User fees can be used to fund particular activities. For example, entry and camping fees in national parks contribute to the maintenance of park facilities, while ecotourism levies in the Great Barrier Reef Marine Park help pay for the administration of commercial activities by the Park Authority and for park management. Resource use taxes, fees and charges are simple to set up and precisely target all and only those involved, based on 'polluter pays' and 'user pays' principles. However, they may not be cost-effective, and tend to be bureaucratic, vulnerable to political lobbying and may not trigger long-term behavioural change.

Subsidies and grants are also examples of price-based incentives. These are relatively simple to establish and politically acceptable as they recognise



Ross and Muriel Reid purchased 30 ha of SA blue gum woodland and pink gum scrub near Inman Valley in the Mount Lofty Ranges in 1972 as a conservation initiative. In 1983, they registered the property with the South Australia Heritage Agreement Scheme. Weeds, rabbits and fence maintenance are the main management issues.



The private nature conservation estate in South Australia, established under the Heritage Agreement Scheme (purple), compared with the extent of the public reserve system (green) and indigenous protected areas (brown).



A community restoration planting funded through local and central government grants, Westland.

existing property rights. Agri-environment schemes in the European Union are an example of this type of approach. Farmers are paid to modify their farming practices in particular fields over a 5–10-year period to enhance biodiversity (e.g. reduction or elimination of use of synthetic fertilisers, pesticides and genetically modified crops; restrictions on the timing of particular in-field activities; planting or regeneration of diverse field margin strips of grasses and forbs).³⁴⁹ Given the increasing recognition that agricultural intensification is responsible for native biodiversity decline in eastern mainland Australia,³⁵⁰ there is a case for subsidising farmers to maintain low-input grazing systems in relevant regions. Many government agencies fund particular biodiversity conservation actions through the provision of community grants. For example, biodiversity grants are available in New Zealand from central, regional and local government for activities such as remnant fencing, restoration plantings and pest control. In these cases, there is a direct link between the economic incentive and the biodiversity outcome. Subsidies and grants have several advantages: they can be used to target specific activities, they respect private property rights and can make funding partly dependent

on outcomes (e.g. a proportion of the payment can be withheld until the project is completed). However, they have also been criticised on several grounds: while generating short to medium-term benefits, there is often no guarantee built into the funding agreement about maintenance of the conservation work or activity in the long term. Ongoing funding and monitoring can be problematic; government grant programs can have high transaction costs and be overly bureaucratic, and such programs rely on the interest of stakeholders and their willingness to participate, and are not compulsory. Therefore, they don't necessarily target the most urgent biodiversity management priorities and needs.

An Environmental Services Scheme operated in NSW in the early 2000s and paid farmers to provide environmental services, such as mitigating dryland salinity and erosion, enhancing biodiversity, sequestering carbon, and reducing acid exports (in coastal areas where acid sulphate soils are a problem). Twenty-five farmers in the high rainfall and wheat–sheep zones were paid to change land use on their farms in strategic ways. These included establishing or improving the management of perennial pastures, establishing commercial and environmental plantings of trees and

shrubs, regenerating native vegetation, planting saltbush, undertaking earthworks to control runoff or drainage, or reintroducing natural wetting or drying cycles in former wetlands or estuarine areas.³⁵¹ While resulting in some positive biodiversity outcomes on the 25 properties involved, the scheme was not expanded beyond these farms and has now been discontinued.

Quantity-based incentives such as tradable permits are widely used in developed countries for the management of scarce resources such as water. For example, in the Murray–Darling Basin, water trading rules are a key component of the strategic plan for water resources (the ‘Basin Plan’) prepared by the Murray–Darling Basin Authority under the commonwealth’s *Water Act 2007*.³⁵² In New Zealand’s Lake Taupo catchment, landowners can trade nitrogen credits, with the aim being to maintain a cap on the total amount of nitrogen leaching into the lake. From a biodiversity perspective, tradable permits have been mainly applied to species. For example, the fish quota system in New Zealand sets a maximum allowable catch, but individual fishers are able to trade quota within this limit. Carbon

credit trading has the potential to yield significant biodiversity gains in agricultural landscapes, where individual farmers can sell credits and gain income for sequestering carbon, such as establishing restoration plantings or facilitating natural woody regeneration, with major benefits for native biodiversity. New Zealand’s Permanent Forest Sink Initiative is discussed on pages 93–94. Tradable permits work best when focused on a single resource or species. They can induce collective responsibility, be well supported by stakeholders and enable the integration of conservation into mainstream business. However, tradable permit systems work poorly when there are many users of a resource with different environmental impacts, they can involve substantial administrative and compliance costs, and they are likely to be more difficult to apply to biodiversity than to a single resource like water.

Liability and compensation may be considered to be quantity-based in that they represent a financial cost associated with particular activities that a person or organisation can choose to accept as part of their business. Liability relates to the risk associated with a particular



The New Zealand emissions trading scheme is both a price and quantity-based system designed to reduce carbon emissions through increasing the cost of carbon (fuel) use but rewarding activities that sequester carbon such as tree planting (Douglas fir in the above photo) by allowing land managers to sell carbon credits.



Water licenses are an example of a quantity-based approach to regulating resource extraction, with a cap on the overall level of diversions in a catchment and the market determining the value per megalitre.

activity and individuals or companies may take out liability insurance to cover adverse outcomes from their activities. Compensation relates to the cost one pays for compensating unavoidable damage resulting from one's activities. Liability and compensation are closely tied to regulatory frameworks and are often a requirement when a government agency, or in New Zealand local or regional government, grants permission to undertake a particular activity (e.g. vegetation clearance). Biodiversity offsets are probably the best known form of compensatory payment. In an offsetting situation, a farmer or developer undertakes actions aimed at offsetting their biodiversity impact and ensuring no net loss, or preferably a net gain, of biodiversity values. This may involve building new habitat (e.g. undertaking restoration plantings or restoring an ecosystem), implementing some form of periodic management to counter a persistent threat to biodiversity (e.g. predator control), or providing long-term security for a site that currently enjoys no environmental protection (e.g. through an appropriate covenant). Offsetting is discussed in more detail on



Predator control (a dead possum in a Timms trap) along with restoration plantings is a common form of compensatory action undertaken in New Zealand to offset impacts on native biodiversity.

p. 90. Liability and compensation are positive as they result in individuals or companies taking care to reduce risks associated with their activities, acting as a strong incentive for environmentally friendly behaviour, and resulting in no net loss or a net gain in biodiversity. However these mechanisms also have disadvantages, including the time, cost and stress associated with recovering liability payments through the court system, argument about what constitutes appropriate compensatory actions, and difficulties in providing ecological and economic guarantees to ensure the long-term sustainability of compensatory actions, since the impacts (i.e. habitat loss) are absolute.

Market-based incentives describe situations where farmers are able to obtain market access or a better price for their product by producing it in a particular way and conveying this distinction to the buyer. The classic example of a market-based incentive is organic agriculture. The ability to access a restricted market usually at a higher price may be part of the incentive for a farmer to produce organically. Several criteria need

to be met for a market incentive to work. There has to be a demand for the product over and above competing products, the product needs to be readily distinguished from competing products (a recognisable label), and there needs to be a system in place to provide assurance to purchasers that the product actually meets the standards that are claimed of it.

There is a wide range of approaches to obtaining a market advantage based on environmental considerations for a product. These range from simple claims that a product is 'natural' or 'green', through to sophisticated certification systems that include independent auditing of product production and marketing with a recognisable brand. Environmental certification systems are discussed in the case study on p. 101. An important distinction is between products or production systems that have ISO 14001 accreditation and those that are fully certified. The ISO system is about having environmental management systems in place, while certification systems operated by, for example, the Forest Stewardship Council³⁵³ or the Leaf Marque label³⁵⁴ are about the actual outcomes of environmental management. Put simply, the former is about having planning procedures for environmental management in place with frequent audits verifying continuous improvement in the planning process, while the latter is about implementing plans and achieving positive outcomes for biodiversity and other values on the ground, with frequent audits to evaluate the quality of the biodiversity gains.



Organic kiwifruit from New Zealand – an example of a market-based incentive that has benefits for biodiversity.

From a farmer's perspective, market incentives are attractive as they provide a financial reason for considering biodiversity as part of the production system – if the system requirements are not met market access is denied. They are also appealing to farmers as they are voluntary, although market access restrictions increasingly make them effectively compulsory. For example, New Zealand Merino growers wanting purchase contracts with clothing companies like Icebreaker and SmartWool need to meet the New Zealand Merino Company Zque certification requirements, including no mulesing.³⁵⁵

Agricultural market incentives, especially comprehensive ones covering a range of environmental issues associated with farm management, are still in their infancy compared with their uptake in production forestry. However, there is increasing pressure from affluent markets (e.g. in Europe, North America and Japan) for products to be produced in an environmentally sustainable manner, including animal welfare considerations. Australian and New Zealand farmers need to be proactive over these issues and develop sector-wide or even cross-sector approaches to developing internationally recognised labels that differentiate local meat, grain, fibre and dairy products from those produced by competitors. However, to be successful, such labels need to focus on not only the things that we already do well (animal and human ethics) but also on the things that require further work, especially relating to environmental issues (carbon sequestration, water quality and of course conservation of native biodiversity).

The advantages of market-based incentives include the potential to affect a whole economic sector with a relatively small investment, and the support of innovation (e.g. as has occurred with organic farming). Market incentives can give farmers market advantage or at least ensure market access, and increase consumer choice, which further drives farmer behaviour. Market incentives are also a positive way for producers and consumers to engage, and can result in positive long-term changes in land management. However, market incentives are vulnerable to patchy consumer interest, especially during economically difficult times, confusion in the market about what different 'eco-friendly' labels mean, and uncertainty about the veracity of claims of



Certification requirements affect the way farmers manage their properties from both an animal welfare and environmental perspective.

product differentiation.³⁵⁶ Finally, there is poor uptake of this type of approach in countries with emerging economies, so the pressure on farmers in Australia and New Zealand to alter behaviour only exists if they are selling into a market that is responsive to ‘eco-friendly’ products. Market forces, however, also drive agribusiness to promote high-input farming systems and increasing sales of agricultural inputs to clients, resulting in agricultural intensification and generally negative native biodiversity outcomes. Given this, there is a clear need for government to develop policy to counter this market pressure and assist the agricultural sector to develop market-based environmental accreditation schemes and fund consumer awareness and education programs.

Voluntary incentives

A variety of mechanisms can be referred to as voluntary, the key distinguishing feature being that the landowner has discretion to participate. Examples include participation in landcare, entering into conservation



Landcare awards recognise the excellent work of leading farmers in natural resource management in Australia, like these farmer representatives of the Lower Apsley River Landcare Group pictured here, winners in the 2007 NSW state awards. (Photo: Kären Zirkler)

covenants or management agreements, and personal management decisions (e.g. fencing a remnant or planting native trees in a shelterbelt). Some financial mechanisms are also essentially voluntary as landowners have the choice to participate – for example, applying for a subsidy or grant when there is no requirement to do so. A key component of voluntary incentives is personal choice, and this in turn is strongly influenced by knowledge of the biodiversity values present. Several examples of voluntary actions are given in the case studies.

Voluntary incentives have high acceptability in rural communities and present minimal equity or property rights issues. These incentives help promote a land stewardship ethic and can be readily reinforced by various environmental award systems (e.g. the Ballance Farm Environment Awards in New Zealand, and the regional, state and national landcare awards in Australia). They are tremendous advocacy tools in the sense that environmentally successful farmers are role models for others, engendering fundamental change in expected and normal behaviours and environmental management standards in rural communities. However, by definition, voluntary incentives are difficult to target, are sensitive to market forces (being more commonly undertaken in periods of financial stability and higher prices), and are difficult to monitor. Most commentators suggest that voluntary mechanisms are important, but should not be relied on as the only means to assist farmers to sustain native biodiversity.

Conclusions

Incentives are policy tools that focus on changing landowner behaviour to sustain native biodiversity in agricultural landscapes, both in remnants and the agricultural matrix. However, in designing and implementing incentive schemes, it is important to consider the property rights of landowners and to address issues of public good versus private cost in terms of where the benefits of biodiversity conservation fall.

In encouraging farmers to sustain more native biodiversity, there needs to be clear recognition that there are both economic and biodiversity realities or non-negotiables: (1) farmers must make a worthwhile profit, and (2) extinction is forever. Given these, the variability of the natural world, the diversity of the



Landcare activities attract large numbers of farmers in rural Australia. (Photo: Kàren Zirkler)

circumstances of individual farming families and agribusinesses, and the turbulence of the agricultural decision-making environment, it is highly unlikely that any one incentive package will be effective in isolation. Regulation is important to ensure that the most important values are not lost (the ecological ‘bottom line’) and that farmers who break the law are penalised. However, if over used or poorly designed, regulation can generate a strong negative ‘backlash’ among landowners, with unwanted and often perverse outcomes for native biodiversity. Voluntary incentives are important, especially because they help nurture an ethic of stewardship and are likely to see long-term change in the way that native biodiversity is managed in rural landscapes. However, they are difficult to target where the need is greatest, and are sensitive to prevailing economic conditions. Market incentives provide an economic rationale for behaviour changes that are, in a sense, voluntary (i.e. farmers can choose to partake) and can also lead to long-term (inter-generational) behaviour changes. The key is to use a mix of persuasion and incentives to help farmers include biodiversity conservation as a core consideration in their farm business. However, to enable any incentive program to work, there needs to be good information provision to the farming community about biodiversity values, the native plants and animals present on their farms, the role of wildlife and vegetation in ecosystem service provision, and the options for conserving biodiversity.

13

MANAGEMENT PLANNING AND GOAL SETTING

Sustaining native biodiversity in agricultural landscapes requires clear goal setting and integrated management. To try and manage biodiversity separately from other farm management considerations is a recipe for failure. As several of the case studies have highlighted, biodiversity conservation needs to be integrated into overall farm management so that the interdependencies between biodiversity and all the other farm enterprises and assets (e.g. soils, pastures, crops, livestock) can be fully accounted for, both in day-to-day management and in the costs and benefits of different activities. Central to integrated management planning is the need to set realistic goals for key aspects of the farm business, including biodiversity, and to monitor management outcomes against these. This chapter explores these issues.

Integrated management planning

While individual farms are often very different from each other, all farm businesses require good planning to ensure continuing viability.³⁵⁷ Farm businesses differ from many other types of business because of the complex interdependencies between the different factors that influence their productivity, including the abiotic environment (weather, soils, water), the biotic environment (crops, trees, livestock, native biodiversity, pests) and the socio-economic environment (markets, the financial system, politics, regulation and stakeholders). Because of this, integrated management planning is essential to ensure long-term business viability. This is especially so if native biodiversity is to be considered a core part of farm management. Two factors are increasingly making management planning a necessary part of

farming: (1) development approval requirements such as resource consents, and (2) the need to be able to demonstrate sustainable land management as part of product marketing. Without integrated management planning, biodiversity is unlikely to be properly included in the farm business plan. However, to date, environmental farm management planning, especially incorporating biodiversity conservation, has been fragmentary in both Australia and New Zealand.³⁵⁸



Integrating biodiversity and farm management requires good planning and attention to detail. Here a native timber shelterbelt is being established on a grazing property.



All aspects of farm management require good planning to ensure ongoing viability, whether it be ensuring appropriate feed (in this case lucerne) or biodiversity conservation.

Society, primarily through national, regional and local government and through various government agencies, has become increasingly involved in regulating farming activities in rural Australia (e.g. through vegetation clearance laws) and New Zealand (through the *Resource Management Act 1991*). Regulations have focused on the way farmers manage their land and have encouraged debate among the broad range of groups that believe they have a stake in rural land management (e.g. local communities, NGOs, local and regional authorities, government agencies). As a result, planning regulations have increasingly been used to ensure that farm management activities are open to broader scrutiny. In New Zealand, district and regional planning regulations oblige farmers to obtain resource consents or other development approvals for activities as diverse as native vegetation clearance, irrigation, burning and even tree planting and the creation of new farm tracks, with in many cases the right for stakeholders to have input into the decision making process. Increasingly, farmers are



Intensively managed grazing systems are often able to integrate a large amount of native biodiversity with pastures, livestock, shelter and water resources, as in this Mount Lofty Range landscape.

being required to show how their proposed development activity fits within their broader farm management.

The nature of the farming industry has also been changing, especially with respect to the marketing of farm products to offshore customers. Supermarket chains in Europe and North America are increasingly asking questions about the way that animals and the land they are reared on are managed in the production of meat and dairy products, while the clothing industry has started to use environmental images as a way to distinguish wool products from synthetic fibres. Mulesing has become a key issue for Merino growers, while many farmers and horticulturalists have achieved organic accreditation as a way to obtain better prices or market access for their products. Markets in Europe, North America and Japan are asking for more information on the way farm products are produced and, in particular, the way that the land, including native biodiversity, is managed as part of food or fibre production. International schemes such as LEAF (Linking Environment and Farming)³⁵⁹ may become a requirement for New Zealand and Australian producers who wish to sell into particular UK markets, and similar schemes are developing elsewhere. The focus of LEAF is on profitable agriculture that is both environmentally and socially responsible. All of these systems require farmers to meet particular standards in the way they manage their animals and land in order to be able to sell farm products into particular markets. Although companies marketing products may require growers to meet particular standards, consumer understanding of certification systems is still poor despite the fact consumers preferentially purchase certified products.³⁶⁰

As well as assisting farmers address these issues, integrated management plans encourage farmers to develop and record their goals and objectives for the property, formalise their own best management practices, and communicate them to farm employees and contractors. Through a formalised monitoring program, management plans can assist farmers identify emerging problems before they become major issues.

Integrated management plans are likely to be particularly important in communicating and verifying to stakeholders, regulators and markets the way in which a particular property, including its native biodiversity, is managed. When linked to a set of management policies, standards, targets, indicators and a monitoring program,



Shelter is important for animal welfare but can also foster biodiversity conservation. This shelterbelt on a Canterbury Plains arable farm includes both radiata pine (pruned to improve its timber value) and native shrubs and small trees.

management plans become the central component of the means of auditing and assuring the quality of the environmental and animal welfare practices and procedures for a property. Management plans do not, in themselves, provide any guarantees about how a property is managed, but they do provide a framework to assist farmers achieve their business and management objectives consistent with their values and vision for the farm and their personal lives. They also provide a framework for auditing farm management and business performance. The inclusion of appropriate goals and performance indicators in a management plan can be tailored to meet the auditing requirements of any certification scheme that a farmer might choose or be required to join.

For example, in New Zealand, the 'On-Farm Quality Assurance Programme' of Canterbury Meat Packers has a number of requirements and recommendations that fit comfortably within a management plan framework. The lamb section includes the following auditing requirements:

- 'Exposure to extreme climatic conditions must be minimized. Sufficient shelter and feed must be available to ensure ongoing live weight gain of growing livestock
- 'Withholding periods for chemicals applied to grazed pastures must be adhered to

- 'All waste, including effluent, offal, chemicals and oils including their containers must be disposed of in accordance with Regional Council by-laws and regulations.'

These requirements can be built into the goals and management tools sections of a farm management plan, with verification built into the monitoring section in order to meet the Canterbury Meat Packers' requirements. The LEAF Marque standard in the UK has a more demanding set of requirements for their audits, which again can be accommodated in a farm management plan framework.

The key components of an environmental and animal welfare certification system are likely to include:

1. **Farm management plan**, which provides the vision, goals and strategic approach to management
2. **Environmental guidelines**, outlining best management practices, which are increasingly being produced by regulators (e.g. regional councils and government agencies) and industry sector groups³⁶¹
3. **Auditing standards**, which ensure that the goals of the management plan and environmental guidelines are being met in farm operations.

The relationships between these different components are summarised in the figure below and are central to the whole concept of sustainable farm management.

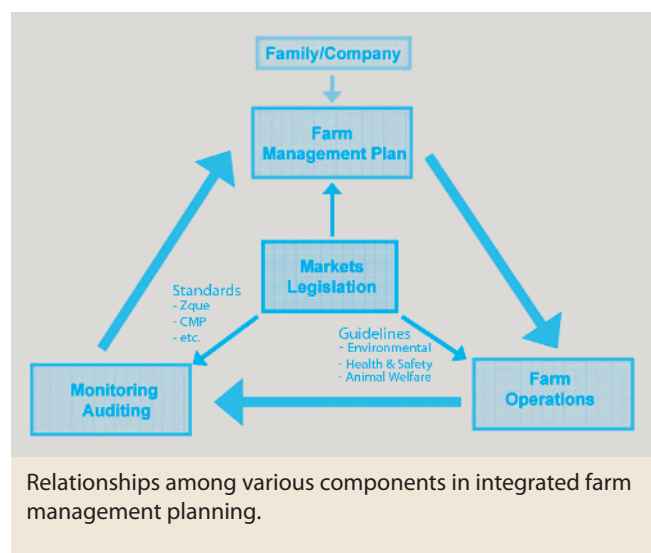
There is no one correct management plan structure: approaches to plans vary between sectors, regions and markets. However, integrated farm management

plans are likely to include seven key elements (see the table opposite).

Not all management plans necessarily cover all these issues, or they may include additional sections depending on the local situation. The amount of detail included in each section can vary. In short, there is no one 'correct' approach, the key point being that the detail included is sufficient to meet the needs of the particular situation. However, two key components should be included in all management plans: (1) clear, time-specific, management goals with appropriate performance indicators ('what outcome by what date'), and (2) a monitoring program that enables objective assessment of the success of management in achieving farm goals. These two issues are now discussed in more detail with specific reference to managing native biodiversity.

Goal setting

Goal setting is without doubt the most important part of a management plan as it describes the farmer's vision and the goals that need to be met to achieve it. Unfortunately, goal setting is one of the most overlooked aspects of management planning, especially in relation to biodiversity conservation and natural resource management.³⁶² The vision is a general statement about how the farmer would like to see the property in the future (perhaps when it is handed on to the next generation). The vision ideally includes a set of more specific outcomes that need to be met if the vision is to be achieved. The vision and especially the management outcomes are likely to have a relatively long time frame –



An Australian farm with plenty of native biodiversity.

Key elements of a farm management plan.

	Management plan element	Comment
1.	Legislative, market, environmental and socio-economic context of farm business	Context within which the farm is located and which shapes vision and goals that are appropriate and possible for the property, including an outline of the farm management philosophy (e.g. a commitment to organics or holistic management)
2.	Opportunities and constraints for farm management	Factors that facilitate or limit what can be achieved (e.g. location close to a major tourist centre, or presence of a limiting soil type)
3.	Vision and goals for property	Both long-term vision and short-term goals for all aspects of farm management (economic, environmental, succession planning)
4.	Summary of current property management	Basic approach towards farming (e.g. income streams, staff, contractors, infrastructure, annual calendar of activities)
5.	Division of property into management units	Environmental and socio-economic division of property (e.g. high-input vs low-input areas, different topographical units), including specific goals for each
6.	Strategic approach to different aspects of property management	Covers individual management components (e.g. stocking; crop management; pasture improvement; pest, weed and disease control; native biodiversity management). Each requires sufficient detail to guide day-to-day management but should not be prescriptive in specifying specific management actions to be undertaken
7.	Monitoring	Methods to assess if management goals are being reached

perhaps 30 years. However, in order to achieve the farm vision and management outcomes, short-term (perhaps five-year) management goals need to be identified that outline the management steps that will be taken to meet the vision. Five years is short enough to be achievable, but long enough to evaluate progress towards long-term outcomes. As each five-year period elapses, a new set of goals needs to be developed.

Both the vision and management goals may incorporate the requirements of an external stakeholder (e.g. a market audit system). However, it is more likely that the vision and goals primarily reflect the farmer's own vision and plans for the property.

Visions need to be challenging, but achievable. The following is an example:

The economic potential of the property is being fully utilised while maintaining and, where appropriate, enhancing other values present (especially native biodiversity), in a manner that is resilient, dynamic and flexible.

This vision is general and a set of more specific outcomes should be included if the vision is to be realised. Outcomes might include some or all of the following:

- The property is an economically viable farming unit

- The property provides for the family's needs, including succession planning
- Farm management is a multifaceted and sustainable operation
- Animal welfare issues are a central consideration in farm management
- Significant natural values on the property are being sustainably managed
- Management activities are monitored.



Successful biodiversity conservation requires a financially viable farming operation.



Woody weed management is a good example of where management actions need to be staged to ensure that management can be sustained, especially on large properties, Mackenzie Basin.

The vision and these outcomes cannot be achieved overnight, both because of the resources that need to be invested and because ecological processes work on long time frames. It is therefore essential that day-to-day management is based around a series of shorter-term goals. It might be possible with some management issues to meet a 30-year outcome in five years, but in most cases this will not be the case (e.g. controlling an invasive weed). Hence, incremental steps in the desired direction are fundamentally important. Each five-year management goal needs a corresponding performance indicator. This is used to measure the success of management in achieving the goal and can also be related

to standards associated with environmental and animal welfare auditing systems.

The table below gives an example of an incremental approach to tackling a management issue through a sequential series of five-year management goals for a farm. The example relates to the control of wilding conifers of Douglas fir, European larch and several pine species, which are major economic and biodiversity weeds in New Zealand rangelands.

The tables opposite provide two examples of management goals and performance indicators taken from a management plan from one New Zealand rangeland property.

Incremental approach required for goal setting using wilding conifer control as an example.	
Years 1–5	Map extent of wildings, remove main seed source trees and remove outlier trees
Years 6–10	Remove remaining clusters of cone-bearing wilding trees originating from original seed sources and continue removal of outlier trees
Years 11–15	Control any regeneration at sites where removal occurred in years 1–10 and continue removal of outlier trees
Years 16 onwards	Maintain annual control of wildings across property on a five-year rotational basis (covering whole property every 5 years)

Goal: increase average Merino weaning percentage

Explanation: lamb mortality represents a significant cost to a high country farming operation both through loss of potential replacement ewes and through loss of store lambs. Weaning percentages are influenced by genetics, health and weather. Some of these are easier to manage than others (e.g. weather is difficult to manage for). Notwithstanding this, weaning percentages can be increased through management of a number of factors including animal health and shelter

Performance indicator: weaning percentages have reached 100%, on average, in 5 years allowing for weather conditions

Goal: sustain aquatic values in stream systems

Explanation: Angelic Downs Station contains a diverse and rich aquatic biota associated with braided rivers, streams and tarns that occur across the property and are a special feature of this property. In order to sustain these values it is essential to establish appropriate monitoring to establish current conditions. Farm management practices can lead to degradation of waterways either directly through stock damage or indirectly through nitrate runoff (especially adjacent to cultivated and irrigated paddocks). Riparian fencing together with riparian plantings and wetland restoration can be used to mitigate these impacts

Performance indicators: (1) a stream monitoring program has been established; (2) riparian fencing and plantings have been established along one creek



Lamb percentage at weaning is a key indicator for any sheep farming operation. Merino ewes and lambs, Mackenzie Basin.

New Zealand's National Parks Act 1980 (Section 4)

(1) It is hereby declared that the provisions of this Act shall have effect for the purpose of preserving in perpetuity as national parks, for their intrinsic worth and for the benefit, use, and enjoyment of the public, areas of New Zealand that contain scenery of such distinctive quality, ecological systems, or natural features so beautiful, unique, or scientifically important that their preservation is in the national interest.

(2) It is hereby further declared that, having regard to the general purposes specified in subsection (1) of this section, national parks shall be so administered and maintained under the provisions of this Act that:

- (a) They shall be preserved as far as possible in their natural state:
- (b) Except where the Authority otherwise determines, the native plants and animals of the parks shall as far as possible be preserved and the introduced plants and animals shall as far as possible be exterminated.

Biodiversity goals

What are appropriate goals for native biodiversity in agricultural landscapes? The overriding goal of biodiversity conservation is to maintain those species and ecosystems that are unique to a place. It is usually assumed that the best way to achieve this is to preserve the pristine natural condition, which is usually equated with the pre-European settlement condition.³⁶³ While this might be a laudable goal and is frequently found in protected area legislation such as the New Zealand *National Parks Act 1980* (see adjacent box), it does not take into account the realities of present-day Australia and New Zealand, and is particularly inappropriate for agricultural landscapes.

Biodiversity conservation goals in agricultural landscapes have to be flexible and reflect the realities of current and likely future conditions, rather than trying to turn the clock back.³⁶⁴ This approach does not mean that we should forget the past and swap kiwi and kangaroo for stoats and foxes as our national emblems. The past is critical as it has shaped our modern biota and, more importantly, tells us what is unique to a place. No-one wants landscapes populated only by wheat, starlings and radiata pine. However, it is not possible to be free of all introduced species or to conjure up extinct species. Nor does it make sense

to be free of human influence in farmscapes: farmers maketh the farm, and they produce food and fibre to make a living. In the end, biodiversity conservation can only be as successful as people want it to be. Goals must be based on the uniqueness and importance of the native biota in an area. Goals must recognise the realities of modern agricultural landscapes, and reflect the aspirations of the people that live there. Biodiversity conservation goals that fail to account for the profound changes that have occurred to native biodiversity since European settlement are bound to fail.³⁶⁵

In the light of the above, we suggest four propositions that should underlie biodiversity conservation goals in farmland:

1. Goals are likely to differ from place to place, reflecting differences in native biodiversity, farming systems and farmers' aspirations: one size does not fit all.
2. Sustaining native biodiversity needs to be a key focus for farm management planning, but needs to be placed in the context of ongoing farming activities and the realities of modern agricultural landscapes, including invasive species.

3. Individual farmers (if planning is just at the farm scale) or groups of farmers (district- or catchment-scale planning) need to take the lead in setting conservation goals and developing management plans for biodiversity on their land.
4. Local biodiversity goals should align with broader regional and national conservation goals, but be developed from the bottom up rather than top down.

While the overarching goal is to sustain native biodiversity unique to an area, goals need to recognise that this may be achieved through creating or sustaining novel mixes of native and exotic species³⁶⁶ rather than focusing only on reconstructing previous native ecosystems. Biodiversity conservation goals also need to focus on ensuring the viability of native species, rather than just aiming to have a particular assemblage of species present.

Goals may comprise a number of components, including some or all of the following:

- Ensuring the persistence of a particular species (e.g. a charismatic species or a species that plays a key functional role). This component is likely to



Establishing restoration plantings, here along a riparian zone, is an achievable biodiversity goal for many farms.



Healthy populations of natural predators of farm pests should be a management goal on every farm.

include a strong social element: local communities might perceive a species to be particularly important and its persistence to be a key aim, such as grey-crowned babblers in cotton catchments in the northern Murray–Darling Basin or tui in many New Zealand rural districts

- Conserving a satisfactory level of species or community viability. The key issue here is ensuring the particular species or community persists into the future. Assessment of this might involve the reproductive success of a species (e.g. annual recruitment of Murray cod) or the maintenance of a particular ecosystem process such as regeneration after fire or windthrow
- Increasing native biodiversity in the landscape across a wide range of taxonomic and functional groups. Success in this goal might be measured by the number of native species present, especially across different groups of native plants and animals (e.g. canopy trees, beneficial insects and spiders, fruit dispersing birds, decomposing insects)
- Improving the values of existing remnants through buffering, increasing habitat area and improving connectivity
- Providing or maintaining key ecosystem services (e.g. clean water, erosion mitigation or natural pest control)



Biodiversity goals in farmscapes can be as simple as maintaining an element of native species in the landscape such as native trees in shelterbelts, South Canterbury.

- Sustaining aesthetic values (e.g. perpetuating the presence of an iconic species in an area, such as kereru in rural New Zealand).

Monitoring: the essential feedback loop

Monitoring provides essential feedback on the outcomes of management interventions. After goal setting, it is the next most important part of farm management planning. Monitoring is important for quantifying the outcomes of farm management, meeting the goals of environmental and animal welfare auditing programs, providing assurance to external stakeholders that management actions are meeting regulatory or auditing requirements, and as a more general advocacy tool for showing how farming is meeting local, regional and national objectives in sustainable land management and native biodiversity conservation. To be most effective, monitoring should focus on the specific performance targets set for individual management goals and quantify the success of management in meeting these goals. Monitoring is an integral part of adaptive management³⁶⁷ in that management actions should be modified (adapted) if monitoring suggests that goals are not being met. For example, monitoring may show that a particular stocking density is having unacceptable impacts on vegetation cover and hence stocking rate or grazing management needs to be altered.

Many farms already measure a range of indicators of management actions such as weaning percentages,

crop yields and soil fertility. With increasing focus on environmental issues, additional management actions may need to be monitored. A diverse range of monitoring indicators is available depending on the type of farming operation and the particular values of the property (e.g. the biodiversity present and public access across or to the property). The challenge with monitoring is to make sure that it is achievable in terms of the resources required (finance, time and technical input) and the information provided. It is sobering to reflect that a review of rangeland monitoring programs undertaken by government agencies and research institutes in New Zealand found that the majority were never re-measured and, of those that were, the results were rarely if ever written up and disseminated to key stakeholders.³⁶⁸

To be effective, monitoring should be undertaken on a regular basis (e.g. every 1–2 years). The methods used should be clearly documented to enable accurate repeat measurements, and the results stored in a manner to ensure that they are safe and available for subsequent analysis. Modern technology (bar codes, GPS, digital photography, GIS, etc.) means that it is increasingly easy to undertake, store and display the results of on-farm monitoring.

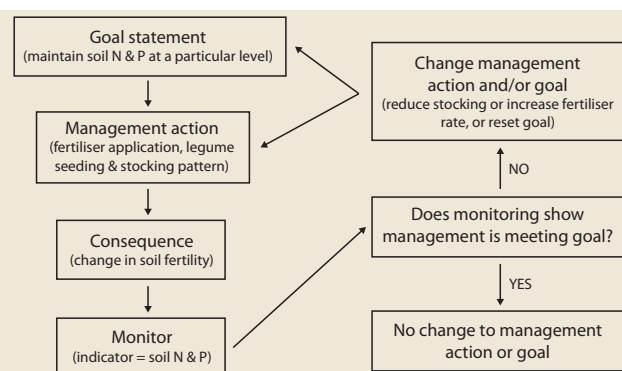
Photo-point monitoring for biodiversity

Native biodiversity monitoring presents particular challenges for farmers as they are usually not biologists and do not have the skills or time to undertake detailed assessments of species abundance. One simple method that enables farmers to track change in biodiversity over several years is photo-point monitoring.³⁶⁹ In essence, photo-point monitoring involves taking repeat photos of the same scene from the same place over several years. If undertaken properly, photo-point monitoring can be used to assess the response of vegetation to a treatment such as fertiliser addition or change in stocking rate or type, and document long-term changes in land cover across the property.

The location of photo-point monitoring sites depends on the focus of the monitoring. For example, if monitoring aims to record overall property condition, then photo-points need to be representative of the range of environments present across the farm (e.g. flats and hillslopes). However, if the focus is on assessing

Monitoring attributes relevant to a sheep and beef cattle farm.

Type	Indicator
Economic	Animal numbers (number/ha)
	Average animal body weight (kg/animal)
	Weaning percentages (per ewe, cow or hind)
	Wool clip (kg/animal)
	Soil fertility levels (nitrogen, sulphur, phosphorus, cations, pH, etc.)
	Agrichemical use (litres/animal/yr or litres/ha/year)
	Fertiliser use (tonnes/ha/year)
	Carbon footprint (balance between emissions and sequestered CO ₂ -equivalents)
Environmental	Density of particular plants – trees, tussocks, etc. (numbers/ha)
	Native species richness (number of species/plot)
	Abundance of indicator species (e.g. cover of key palatable species)
	Native animal numbers (e.g. counts of particular species)
	Bare ground (percentage cover)
	Weed abundance (percentage cover)
	Pest animal densities (e.g. rabbits)
	Stream health (e.g. nutrient levels, invertebrate community composition or water clarity)
Public access	Number of visitors
	Track or hut usage



Relationship between management plan goal setting and monitoring using soil nutrient status as an example.

the effects of a particular management action, such as fertiliser addition, then monitoring needs to be more focused, perhaps only considering the treated area and a similar untreated area for comparison (with replicate photo-points of each).

Ideally, photo-points should be marked permanently (e.g. a steel fence post or metal standard). Trees are not good reference points as they can be cut down or blow over. Photo-points should be numbered using a permanent label and, if possible, their location recorded using GPS technology. Two types of photos can be taken from photo-points, panorama and vegetation composition, and both can be taken from the same point:

1. **Panorama (or landscape) photos** provide a broad overview of land cover (e.g. on an adjacent hillside). The key consideration for panorama photos is to ensure that the view being photographed will not be blocked by changes in the foreground in the foreseeable future (e.g. tree growth or new buildings). For easy rephotographing, it is useful to include distinctive topographical features in the photo such as ridge lines or creeks.
2. **Vegetation composition (or close-up) photos** focus on the vegetation in the immediate vicinity of the photo-point and can be used to assess vegetation composition and the amount of litter and bare ground at a site. These can be combined with quantitative measurements of vegetation cover, although this is not essential. Having a reference point in the photo (e.g. a metal standard)



A monitoring transect on a mid-Canterbury high country farm that is being used to monitor vegetation composition by measurements and through repeat photographs.

is important for ensuring that the same area is photographed each time. Vegetation composition photo-points are best located at least 20 m from the nearest fence, water trough, tree, hedgerow, track or building, as these modify stock behaviour and hence vegetation composition.

When taking photos, it is important to record some basic information including photo-point number, date and time, weather conditions, and notes on the orientation of the photo. When rephotographing a site, it is best to take copies of the original photos to ensure that the same scene is photographed. Photos will normally be taken only once each year and should be taken at the same time of year, at a similar time of day and under similar weather conditions. Spring and autumn are



Photos taken in 1995 and 2007 from the same location showing loss of native tussocks and expansion of the woody weed sweet brier in the eastern South Island.



Photos taken four years apart along the same transect in rangeland showing decline in tussock vigour and density most likely due to mouse-ear hawkweed (with yellow flowers) outcompeting the native tussocks for water.

difficult times to take photos as vegetation colour can change rapidly as plants flower and put on new growth, or when vegetation dieback is occurring. The best time is early to mid summer.

Various options for analysing and interpreting photos are available. The easiest is a subjective assessment of the major changes observed, for example 'expansion of woody plants' or 'decreasing area of exposed soil.' This assessment might be simply noted by the farmer, but more usefully any changes observed can be written down on a photo record sheet for future reference. Photos can also be analysed quantitatively (e.g. using a grid and recording the species cover in grid-squares, or using computer image analysis software to quantify vegetation cover), but this type of analysis is time-consuming and not usually necessary.

Photos need to be properly annotated and stored as soon after they have been taken as is practical. This is important because the longer the photos are left, the more likely they will be deleted, misplaced or lost, and because the observer's memory is best immediately after the photos are taken. As photos these days are taken using a digital camera, it is recommended that the photos are downloaded and saved on to a computer straight after they are taken. It is important to label each photo with the photo-point number and the date the photo was taken. Monitoring data should be treated the same as farm financial records, with one or more backup copies kept in different locations (i.e. buildings) to the office computer.

Conclusions

Integrated management planning is important for bringing biodiversity into mainstream farm planning. Treating biodiversity as separate or outside normal farm management activities runs the risk that it will become marginalised and not properly considered. Farm management planning enables farmers to undertake day-to-day management activities within the context of their long-term objectives. By including biodiversity conservation in farm management planning, it is possible to ensure that the complex interconnections between the different facets of farm operations and biodiversity are fully accounted for, and to undertake biodiversity management activities in incremental steps. In setting visions and goals for farm management plans, it is essential to ensure that goals for biodiversity are realistic and achievable, and that performance indicators are specified for all management goals. Monitoring can then provide the essential feedback on how successful farm management has been at achieving these goals by assessing outcomes against performance indicators. This is important both for informing the farmer about the results of their management actions, and for providing assurance to external stakeholders (government, markets, etc.) about the management of the property and the food, fibre and other ecosystem goods and services produced from it.

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A WAY FORWARD

As earlier chapters of this book made clear, it is crucial for several reasons to sustain native biodiversity in agricultural landscapes in Australia and New Zealand. Increasing numbers of farmers are willing to consider biodiversity conservation as part of their farm management, and some outstanding examples of where this is already happening have been highlighted. If the ambitious vision of safeguarding nature across the world's farmlands is to be achieved, we need to free ourselves from the sometimes narrow thinking and actions of the past and look to new ways of sustaining

native biodiversity in farmscapes. This is necessary because native biodiversity in agricultural landscapes is important for many reasons including:

1. As inputs to production and drivers of the farm business.
2. As agricultural outputs and commodities, and therefore a source of economic wealth, social esteem and personal worth.
3. As catalysts and drivers of a myriad of ecosystem services to humanity with varying district-



A South Island high-country farmscape with high biodiversity values associated with native forest remnants and alpine grasslands, productive sheep, cattle and deer enterprises, and outstanding tourism and recreation values.

wide, regional and occasionally national or even continental and global ramifications, many of which we are only beginning to dimly appreciate and some of which have probably yet to be revealed.

4. As part of a social contract with the rest of society to be responsible stewards for the time we have on Earth.
5. As a reason for getting up in the morning, for its contribution to local and regional communities' sense of place, and for feeling proud about the current generation's legacy to future generations.
6. Or simply for the sake of the plants and animals themselves.

In acknowledging past mistakes, misunderstandings and prejudices, solutions are required that overcome the obvious constraints of managing native biodiversity in production landscapes. We must seize the many opportunities waiting to be exploited. Above all, the multiple reasons and means by which native biodiversity should and can be sustained in farmland need to be explored in partnerships between farmers and the rest of society based on mutual trust and respect. In short, we need to write a new set of rules for the business of native biodiversity in agricultural landscapes that benefits farmers, agribusiness and society, now and in the future. This chapter outlines how this might be achieved.



Our challenge is to overcome the weaknesses of the past in order to ensure that our unique biodiversity, such as this kereru (New Zealand pigeon) feeding in exotic tree lucerne (tagasaste), is sustained within vibrant agricultural landscapes.

Acknowledge the weaknesses of the past

There are innumerable reasons for why, at the beginning of the 21st century, the world is staring into the abyss of an extinction spasm that will rival the demise of the dinosaurs 65 million years ago or the mass extinction at the end of the Permian some 250 million years ago.³⁷⁰ While we cannot look after the rest of the world, we can do better for native biodiversity in Australian and New Zealand rural environments.

A summary of the recent past, and some might say the present, situation in rural Australia and New Zealand would highlight the sometimes hasty, perhaps even secretive introduction of legislation and district plan rules designed to protect native vegetation and threatened species. These measures have resulted in the forced reservation of remnant natural areas on farms, imposition of conservation orders or infringement notices on development activities already underway, and monitoring of farmers' activities from roads, the air and space. In response to leaks of pending legislation or notification of proposed new plan rules, bulldozers would operate 24/7 to clear as much native vegetation as possible before new laws were introduced. Once the laws were enacted, hurriedly drafted to stem the clearing and therefore poorly crafted, areas of native vegetation would still shrink over time by nick and tuck, and isolated paddock trees in cropping fields would die remarkably quickly. Occasional farmers would disregard the regulations, viewing the cost of fines for illegal land clearing as a business cost in the expectation that the productivity gains would exceed the fine. Meanwhile, for every offender clearing land illegally, there would be many farming families impeded by inflexible regulation, preventing them from proceeding to develop their farms. In some cases, lives would be put on hold, the hopes of a lifetime dashed, and people prevented from supporting themselves and their families, forcing the banks to foreclose after years of stress and anxiety and appeals to sympathetic but powerless agency staff, members of parliament and government ministers, ultimately to the ruination of too many promising lives. It's not a pretty picture, and there are too many of these stories to ignore the past and move forward without considerable hesitation, uncertainty, scepticism and mistrust.



Landcarers preparing tubestock of native trees, shrubs and herbs for a community planting. (Photo: Ellen Nyberg)

But it is not just the lawless farmer who clears native vegetation or the private land placed under protection orders that is the issue. The lack of empowerment that farmers and rural communities feel when inflexible regulation is imposed without consultation is an impediment to better relationships between government, the conservation movement and farming. Empowerment and stewardship might be nebulous concepts but they can only occur when an individual is motivated to act. One of the biggest losses from command-and-control regulation is the loss of desire by rural communities to conserve biodiversity and its replacement by antagonism or hostility towards native biota and natural areas. The importance of open-minded, empowered individuals and rural communities is central to our vision for a sustainable future for native biodiversity in rural landscapes.

So, to avoid past mistakes, we need to acknowledge the failings to date of much biodiversity policy in rural areas, particularly the limitations of inflexible, top-down regulation, the consequences for native biodiversity of transforming natural ecosystems into farmland, and the relationships between farmers and society in relation to heritage conservation.³⁷¹

Limitations of biodiversity policy in rural areas

Command-and-control regulations for conserving native biodiversity in farmland have typically been inflexible and broad in scope, and adopted a one-size-fits-all approach. Farmers know that their management

has to be dynamic and flexible to cope with changing circumstances, and are therefore cautious to commit to anything that limits their flexibility and future management options on agriculturally productive land.³⁷² Regulation is particularly poor in mitigating the tyranny of small decisions, in other words controlling the many small incremental actions of multiple actors. If every farmer in Australia cleared 2 ha legally under exemption each year, the amount of native vegetation destroyed would approximate half of the average rate of vegetation clearance since European settlement. Widespread uptake of exemptions to vegetation clearance provisions in New Zealand district plans would have similar consequences. Blunt regulatory instruments are weak at controlling gradual land-use intensification, for example the loss of palatable native plants from top-dressed and over-sown pastures subjected to increased stocking rates, and do not deal well with the habitat loss and biodiversity decline resulting from invasive species. If legislative solutions are sought, regulations must accommodate the individuality of farms and farmers, their dynamic decision-making environment, and the biophysical, economic and social pressures (the drivers of change – Chapter 6) that lead to changes in native biodiversity, societal attitudes and farmers' priorities through time.

Farmers consider it unfair when their private property rights are restricted by new laws that force them to subsidise the cost of nature conservation on their land for the benefit of the rest of society.³⁷³ They often oppose laws and plans that are driven by urban populations who are not dependent on the land for their income. Whenever possible, policy makers should avoid top-down regulation and rules that restrict landowners' private property rights or impose inequitable costs, because such approaches quickly alienate rural communities and stymies voluntary biodiversity conservation initiatives. Antagonising the farming sector is counter-productive. The farmer is the person on the ground year round with the best knowledge of the values of the property. Farmer engagement, cooperation and empathy, not alienation, are critical to the long-term success of native biodiversity initiatives in agricultural landscapes.

Realistic payment for conservation services should be considered,³⁷⁴ although historically this has been limited, especially in comparison to the expenditure on public conservation lands (national parks and



Regulations often set minimum limits for vegetation clearance, yet very small remnants or even scattered trees, such as these mountain beech on a New Zealand farm, that are not covered by such regulations can still have important biodiversity values: voluntary mechanisms are often better at protecting them.



A landcare-funded biodiversity planting for biodiversity and natural pest control on a NSW farm. (Photo: Rhiannon Smith)

reserves). In New Zealand, significant funding targeting native biodiversity conservation in farmland has only been made available in the last decade or so. The Biodiversity Condition and Advice Fund managed by the Department of Conservation has provided some \$24 million in funding over the last 8 years,³⁷⁵ while individual territorial local authorities and regional councils have their own funds, albeit much smaller,³⁷⁶ to encourage restoration plantings, fencing and pest control for biodiversity outcomes. Australia has a longer history of funding farmers to revegetate their farms or manage land for biodiversity, including the National Afforestation Program (1988–1990), the Natural Heritage Trust (1996–2008, incorporating the National Landcare Program, 1990–2008, as well as the Bushcare and Rivercare programs), and Caring for our Country (2008 to the present), which continues to fund landcare.³⁷⁷ More recently, funds delivered through regional natural resource management and

catchment authorities and federal programs such as Environmental Stewardship have specifically targeted native biodiversity on farms. Notwithstanding the large amounts of money made available under these programs since 1988, the total funds expended amount to annual expenditures on biodiversity in agricultural landscapes of less than A\$0.75 per hectare in Australia under Caring for our Country and NZ\$3.71 per hectare in New Zealand in 2009–11.³⁷⁸ This is scarcely realistic payment for such an important public service. By contrast, annual funding for biodiversity conservation on public land was A\$38.38 per hectare in New South Wales and NZ\$28.05 per hectare in New Zealand in 2009–2010,³⁷⁹ and this is considered by most conservation scientists and NGOs to be inadequate.

Consequences of agriculture for native biodiversity

To avoid the mistakes of the past, we must also acknowledge the consequences for native biodiversity of transforming natural ecosystems into farmland. Most native biodiversity is lost when natural habitats are cleared for agriculture (e.g. the transformation of forest into dairy pasture, or woodland and mallee into wheat). The loss of native biodiversity is proportional to the degree of transformation and the intensity of agricultural use. Consider a grassy woodland earmarked for agricultural development: thinning some of the trees and lightly grazing the area results in the loss of far fewer species of native plants and animals than transforming it into a wheat crop.

The inexorable pressure on farmers to intensify production in the face of declining terms of trade over the past 60 years has been negative for native biodiversity, as farmland has been steadily cleared and developed and land use intensified.³⁸⁰ The original forests and woodlands have been thinned or cleared for grazing. Grassland and native pasture have been fertilised and over-sown with legume and grass seed. In turn, these semi-improved pastures have been ploughed up and sown to introduced pastures. Grazing land has been converted to dryland farming, and rainfed cropland has been laser levelled and converted to irrigation. As a result of these changes, the native biodiversity that occurred in forests, woodlands and grasslands has been progressively depleted. In parallel, paddock and farm sizes have steadily increased in pursuit of greater efficiencies and



Lowland forest clearance for dairy farming, Westland.



The changes that have occurred across the Canterbury Plains, one of the most transformed landscapes worldwide, are such that the number of native plant and bird species seen driving the 160 km from Christchurch to Timaru can be counted on one hand!

economies of scale, contributing to the homogenisation of farmscapes and a reduction in habitat heterogeneity as shelter is removed, remnant trees cleared and wetlands drained. While native plants and animals, including some present prior to agricultural transformation, persist or increase in the modified habitats created by agriculture, the issue for biodiversity conservation is that many species are declining because they cannot adapt to the new agricultural habitats and disturbance regimes associated with the steady intensification of agriculture. Native species that are able to persist in the matrix under present conditions may decline in time as agriculture is forced to adapt to ever-changing external conditions.

Relationships between farmers and society in relation to biodiversity conservation

There is often a lack of trust and respect between the farming community on one hand, and conservationists and conservation agencies and scientists on the other. Part of the problem lies in the fundamental difference in values between farmers and conservationists. Kids on the land grow up with the ethos that agricultural production is good, that feeding and clothing the world is morally right, that running a profitable business and contributing to the nation's wealth is a measure of a farmer's self-worth, and that reliance on someone else's handouts is the antipathy of the independence and ability to provide for one's family that is respected and expected in farming communities. Among farmer values is the notion that productive land not used for agricultural production is a waste, and that people who 'lock up' arable or grazing country to become a haven for weeds and vermin and a fire hazard are difficult to fathom and a menace to rural folk.

Some conservationists, on the other hand, believe that farmers are largely to blame for the extinction spasm encompassing the planet, that there is plenty of farmland already in production and that farmers should better use the land they already have. Some 'greenies' think that farmers who want to become richer at the expense of the last natural areas in a district or region are greedy, and

that farmers do not care about biodiversity or appreciate its importance. These conservationists think that every last natural and semi-natural remnant of native vegetation in agricultural districts should be managed to conserve what is left of the native biota. They think that farmers are a bit precious getting upset about the green lobby's efforts to protect the last bits of native vegetation in farming districts since these areas weren't being used for much anyway.

A problem for conservation agency staff, including those in local and regional councils, is that they are identified with command-and-control regulations that attempt to impose biodiversity conservation on private land by rule of law. Agency or council officers may have to work within a legislative framework that is poorly formulated and inflexible, leading to farmer frustration. Little wonder that farmers, conservationists and agency staff sometimes struggle to find common ground.

Part of the problem is the way the rest of society interacts with farmers. Farmers are often annoyed by scientists and agency staff telling them how to manage their land, especially when the public conservation estate is not well managed (e.g. in terms of weeds and vertebrate pests). Farmers are angered by government attempts to take their land away or enforce protection when their management has preserved the natural values.³⁸¹ Farmers can become particularly irritable when scientists and



Modern intensive farming makes it increasingly difficult for native biodiversity to persist: Canterbury Plains arable farming.



Kids grow up on the land with a strong affinity for the values of their social and biophysical environment. (Photo: Nick Schultz)



Negative sentiment towards government agencies (in this case the New Zealand Department of Conservation) comes out of farmers' frustrations over what they perceive to be inflexible regulation. (Photo: Henrik Moller)



Wheat-sheep farm near Esperance, WA, showing retention of remnant native vegetation on sandy rises and around ephemeral wetlands, and north-south planted pine windbreaks protecting crops and pastures and providing habitat connectivity for wildlife. (Photo courtesy of Garry English)

agency staff claim that the value of the native biodiversity on a property warrants legal protection when the reason it is there is the result of generations of conservative and sustainable farm management, unlike adjacent farms where little native biodiversity might remain. However, it is also important to acknowledge that, like any group in society, some farmers will never be interested in biodiversity conservation, and a few will go out of their way to eliminate native biota, whether through malice, disregard, conviction, diversion or profit.

Fortunately, the situation is not as bleak as we have painted it, although our depictions are evidence-based. Many conservationists have a rural background or have spent considerable time living and working in regional areas, and appreciate the material and societal importance of agriculture and the culture of rural communities. As we have highlighted in the case study section of this book, many farmers are conservationists (although some might eschew that label) and protect native biodiversity on their farms, albeit without much acknowledgement or encouragement.

A new approach

If native biodiversity is to be sustained in agricultural landscapes for the utilitarian, cultural, ethical and intrinsic values we have discussed, a new approach is required because the present one is not working in many instances. Without a new approach, the biodiversity train-

wreck that lies ahead could exceed even our worst fears. The approach we are proposing is based on our vision for native biodiversity in rural Australia and New Zealand:

Our vision is of vibrant agricultural landscapes that sustain both farming and biodiversity, in which native biota prospers and is valued by rural communities, and where the management expertise and efforts of farmers in sustaining native biodiversity is valued by all in society. We acknowledge that the native plants and animals in these landscapes will occur largely in novel ecosystems, not only in semi-natural remnants and restored habitats but throughout the productive agricultural matrix. We envisage a relationship between farmers and society based on mutual trust, respect and understanding: a partnership in which the costs and benefits of sustaining native biodiversity are shared equitably between stakeholders. Governments' role in facilitating this partnership is to provide adequate funding and rewards through a variety of mechanisms to enable landowners to sustain native biodiversity across the rural environment as part of successful regional economies.

Achievement of this vision is dependent on four prerequisites:

- Trust and respect between farmers, conservation interests, scientists and government on the basis of a strong partnership, which identifies multiple ways

forward for sustaining native biodiversity in rural and regional environments

- A commitment by government to introduce a comprehensive package of biodiversity policies and incentives, as identified by the partnership of farming communities, regional authorities, scientists and conservation interests
- A commitment by government to find new funding (rather than funds diverted from other parts of the environment, natural resource and conservation budgets) to fund rural biodiversity programs at levels and for the time required to secure the future of native biota in farming regions
- A new kind of rural advisor ('agri-ecologist') trained in ecological and agricultural science and extension, and whose role is to provide biodiversity information, management and planning advice to farmers, to help them apply for funds, and to encourage ecologists and farmers to work together in developing novel answers and solutions to farmland biodiversity problems.

It is likely that a critical portion of the voting public will support increased funding and new approaches in environmental policy as suggested here, notwithstanding potential future biophysical (e.g. natural disasters) and socio-economic (e.g. global recession) constraints on



Proactive information sharing through field days, workshops and small group discussions is essential for building trust, respect and understanding between farmers and society.

public spending. This public support occurs because of the sustained societal concern about environmental issues, the health of the biosphere and the potential for planetary eco-disaster in the 21st century and beyond, and recent political reforms on the environment such as the enactment of carbon price and emissions trading schemes in Australia and New Zealand.

Our approach to sustaining biodiversity in rural Australia and New Zealand is based on several assumptions:

1. Farmers are in the best position to manage significant native biodiversity assets on their land.
2. Farmers, agencies and government are willing to commit to a new partnership to sustain native biodiversity: farmers are not afraid to be innovative; policy makers are prepared to encourage innovation; NGOs are willing to support innovative farmers, and scientists can think beyond protected areas.
3. Society will applaud new initiatives that achieve their intended objectives, including novel solutions that might raise eyebrows in traditional farming and conservation circles.
4. Society will support payment to farmers for managing significant biodiversity assets in the public interest when it is not in farmers' financial interests to do so privately.
5. Critics on both sides of the fence will permit new approaches to be trialled and evaluated for a reasonable period of time (years rather than months).
6. Agency staff in traditional conservation areas will not seek to redirect funds, which they might see as theirs, and opinion leaders in the farming community will not lobby to see government biodiversity funds spent on what they might see as more worthwhile sustainable land management issues, such as soil conservation and water resource management.
7. Farmers, their lobbyists, agri-ecologists and senior public servants can build enough respect, mutual trust and understanding to sustain and strengthen the relationship.

8. Rural agri-ecologists are able to relate to farmers, provide biodiversity advice and assistance in a non-threatening, non-insulting manner, and help farmers solve their biodiversity problems and conserve native biota.

Notwithstanding the above, there will still be a need for a regulatory framework. The regulatory framework that we envisage is one that facilitates this new approach by giving it standing in law. Without formal support, many of the assumptions discussed above are unlikely to be sustainable. There will also be a requirement for a regulatory 'biodiversity bottom line' to stop farmers who, for whatever reason, ignore the voluntary collaborative approach we are advocating and destroy native biodiversity in a covert way.

A way forward

Conservation agencies, local authorities and NGOs have to trust farmers, and farmers have to trust these groups. It will not necessarily be easy, given the history on both sides. Ideally, the rural ecologists we are proposing as central to this approach are not saddled with old baggage and, in particular, are not perceived to be trying to penalise farmers or take their land away. Conservation interests have to recognise that most farmers want to do the right thing and protect native biodiversity, subject to time, money, feasibility and the likelihood of success. They also have to appreciate that many farmers are hard-pressed and have little room to manoeuvre despite the best will in the world – hence, the importance of external funds. The bureaucracy must understand that farmers vary enormously: getting to 'yes' with landowners may have nothing to do with the size of their holdings or profitability. Most farmers are asset rich and cash and time poor. The average broadacre farm business in Australia made a loss of \$11 310 in 2008–09; overall 68% of farms made a loss after taking into account capital depreciation and changes in livestock, fodder, grain and wool inventories.³⁸² The reality is that the average Australian farmer is broke. Comparable data for the average Australian household in 2008 was a disposable household annual income of \$71 032.³⁸³ In other words, the average farm household in Australia is financially worse off than their city cousins.



The successful conservation of several New Zealand threatened shrub species including Canterbury pink broom requires sympathetic management on farmland.

Given that much of the value associated with sustaining native biodiversity in rural environments is in the public good, society needs to put in place fair and reasonable incentives to make it worth a farmer's time and effort to do this work, taking into account private property rights and the opportunity costs that may be incurred. It might be that farming to sustain biodiversity may be a way for farmers under tight financial constraints to see an economic way forward. In some instances, sustaining native biodiversity is a benefit to the farming enterprise. Examples are where biodiversity provides a direct income source (e.g. timber, or native pasture that sustains meat and wool production) or where biodiversity assists in the marketing of products. In such cases, the farmer benefits directly from managing native biodiversity and in these situations there may be less need for external financial support, although access to new resource management information is often useful. However, in many instances, sustaining native biodiversity will not be compatible with a farmer's existing plans. In these cases, should the farmer agree, the best outcome will be a negotiated

solution, which could involve an offset, incentive, trade-off, compensation or some non-financial benefit that is agreed recompense for a negotiated win-win. Various types of reward might be considered. Examples include greater security of tenure for crown lessees, priority access to licensed resources (e.g. water or grazing on public land), or services such as flora and fauna surveys, scientific investigations, carbon audits, residue testing, assistance with farm development, business and management planning, or provision of satellite imagery and cadastral layers for farm planning.

If we are to make best use of the opportunities for native biodiversity conservation in farmland, everyone needs to think outside the box. Scientists and conservationists have to recognise that farms are not national parks. Worthwhile conservation outcomes on private land can be quite different to the ways in which biodiversity conservation is achieved in protected areas.

Maintenance of cherry trees in homestead orchards might be the best way to help sustain kereru in New Zealand farmland, and camphor laurel food trees may be stepping stones for fruit pigeons in subtropical grazing land on the North Coast of NSW, at least as an interim measure.³⁸⁴ Biodiversity outcomes in agricultural landscapes are going to vary, within farms, across districts and between regions. In some places,



Farmland restoration plantings for biodiversity at Basket Range, SA. (Photo: Lydia Paton)



Restoring biodiversity to farmscapes may well involve a wide range of novel ecosystems with both private and public-good benefits.

management may be intensive (e.g. the construction and maintenance of a predator-proof fence around a remnant). In others, it might simply be the conservation of existing habitat elements or iconic species (roadside eucalypt woodland and mallee in Australian farming districts or cabbage trees in rural New Zealand). However, novel outcomes are likely to be the norm.³⁸⁵

Finally, there is the critical need for a new breed of rural ecologist or agri-ecologist, trained in biodiversity and rural science as well as communications and extension, equally knowledgeable about farming and threatened species, and sympathetic to conservation and agricultural interests. These extension workers need to be trained in the art of talking with people, not talking at them. Such people already exist in New Zealand and Australia, but they are thin on the ground. In the world we envisage, rural ecologists would establish a rapport with farmers and engage their clientele to sustain native biodiversity in agricultural landscapes. They would work with many farmers, raising awareness about the reasons for sustaining native biodiversity in farmland. If asked, they could conduct biodiversity surveys on private land, with the farmer deciding whether they wanted the information in the public domain at some future time. They would extend biodiversity information, respond to requests for advice and connect farmers with appropriate experts and researchers in order to encourage adaptive learning about important unknowns, offer advice about biodiversity funding opportunities, and help farmers lodge applications for support funds. Theirs would not



Despite being declared noxious in Queensland and northern NSW, camphor laurels produce fruit that is eaten by frugivorous birds and fruit bats, perhaps sustaining native bird and mammal movements in overcleared parts of the lowland subtropics.

be a regulatory or compliance role but, when asked, they could advise landowners about their obligations under law.

In our vision, rural ecologists would often have regional if not farming backgrounds and be trained in education, non-threatening communication, and win-win negotiation³⁸⁶ as well as biodiversity and agricultural science. They would be able to access funding programs and other resources to assist farmers conserve biodiversity, everything from free technical advice and biological survey to information about covenants and the funding schemes and grants available through NGOs, the private and philanthropic sectors and government for fencing, restoration plantings, pest control, low-input farming subsidies, farm planning and so on. They could assist with management plans and environmental accreditation, and would be supported with sufficient government funding to support public-good rural biodiversity conservation. Rural ecologists would help farmers sustain the most significant natural assets on their farms, but would also work with farmers in better understanding their matrix management and its implications for biodiversity. The means would be up to the farmer and the need for funds or other support would be part of the negotiation. If all that was required was to maintain current management for the foreseeable future or make changes to improve both farm profits and biodiversity, little might need to be offered in recompense other than advice and support.



Trust and rapport are important elements of the relationship between landowners and their advisers.

If environmental accreditation was an issue, free advice and technical support should be available. If the farmer was intending to manage a key asset differently, offsets or stewardship payments (depending on the farmer's needs and the significance of the asset) might be on the table. If the farmland matrix could be improved significantly for wildlife, funds to implement habitat modifications could be sourced. Importantly, rural ecologists should be able to work with farmers to monitor and report back to them on their biodiversity management activities, and with the farmer's permission, to other interested parties.

Respectful dialogue and discussion would be important. For example, rural ecologists may have information about the management needs of a particular plant or animal that would be useful for the farmer to know. Farmers might have key information about the same organism from a lifetime of observation that was crucial in developing an area-wide management plan for the species. Agreements between the parties would be important to satisfy farmers' needs for information and data collection about a species or community, perhaps in relation to their farm management. The ecologist would require periodic access to check whether the agreed management interventions were working on the ground, and to review management arrangements with the landowner and discuss adaptive changes that might be appropriate. In cooperative projects, farmers might have to agree to discuss any changes in management with the ecologist before acting unilaterally.



Landowners appreciate technical information about how the biodiversity in their paddocks relates to their agricultural production. (Photo: Leah MacKinnon)

It would be better if rural ecologists were not aligned with existing national or state or territory government agencies, which might see their influence and profile disappear within the bureaucracy, nor should they be confined to major cities. They would be better located in existing local management structures, for example district councils in New Zealand and national resource management bodies (e.g. catchment authorities or natural resource management boards) in Australia, based in and as part of the rural communities they serve. With modern technology, especially the rollout of broadband across rural Australia and New Zealand, they would have access to necessary telecommunications.

Conclusions

The prognosis for the native biodiversity of agricultural regions in New Zealand and Australia assuming the *status quo* and present trends is grim. Notwithstanding the significant numbers of species that thrive or are being encouraged to return to production landscapes to fulfil multiple beneficial roles, the extinction debt threatens the survival of many if not most plants and animals in heavily developed farmscapes, despite the retention of small areas of habitat. Farmers and the rest of society need to forge a relationship based on mutual trust, respect and understanding, in the knowledge that both will benefit from safeguarding the future of native biodiversity in agricultural landscapes, with all beneficiaries paying accordingly. In this book we



Cattle grazing native pasture with scattered Bendemeer white gum, a nationally threatened tree, at Blaxland near Walcha, NSW. With the knowledge of the significance of this eucalypt on their property, owners James and Caroline Street plan to ensure its long-term persistence.

have reviewed the nature of biodiversity in agricultural landscapes and the way that agriculture interacts with it. We have highlighted some wonderful examples of initiatives being undertaken by farmers to sustain biodiversity on their properties. In this last chapter we have outlined a vision and a way forward that we believe will see both a sustainable agricultural sector and native biodiversity sustained in these environments. The key challenges to achieving this vision are to get farmers, conservationists, scientists and government talking and developing policy solutions together everywhere. Governments should assist agribusiness embrace market-based environmental accreditation schemes and commit to a progressive network of rural ecologists who can facilitate the positive dialogue and information sharing between farmers and society that is needed to sustain biodiversity in rural areas. This extension network must be supported with realistic funding that recognises the enormous public good and legacy associated with sustaining native biota in farming regions.

ENDNOTES

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LIST OF SCIENTIFIC NAMES OF PLANTS AND ANIMALS

Common name in text	Scientific name		
Acacia	<i>Acacia</i> sp.	Box, western grey	<i>Eucalyptus microcarpa</i>
Alder, red	<i>Alnus rubra</i>	Boxthorn	<i>Lycium ferocissimum</i>
Apple	<i>Malus pumila</i>	Briar, sweet	<i>Rosa rubiginosa</i>
Ash, mountain	<i>Eucalyptus regnans</i>	Brome	<i>Bromus</i> sp.
Babbler, grey-crowned	<i>Pomatostomus temporalis</i>	Broom, Canterbury pink	<i>Carmichaelia torulosa</i>
Banana	<i>Musa acuminata</i> , <i>M. balbisiana</i> or hybrids	Budda	<i>Eremophila mitchellii</i>
Banana passion vine	<i>Passiflora mollissima</i>	Buffalo	<i>Bubalus bubalis</i>
Barley	<i>Hordeum vulgare</i>	Burr, galvanised	<i>Sclerolaena birchii</i>
Bean, faba	<i>Vicia faba</i>	Bush wren	<i>Xenicus longipes</i>
Bear, polar	<i>Ursus maritimus</i>	Bushlark	<i>Mirafra javanica</i>
Beech	<i>Nothofagus</i> sp.	Bushlark, Horsfield's	<i>Mirafra javanica</i>
Beech, black	<i>Nothofagus solandri</i> var. <i>solandri</i>	Bush-pea, prostrate	<i>Pultenaea prostrata</i>
Beech, mountain	<i>Nothofagus solandri</i> var. <i>cliffortioides</i>	Bustard	<i>Ardeotis australis</i>
Beech, red	<i>Nothofagus fusca</i>	Buttercup	<i>Ranunculus</i> sp.
Beech, silver	<i>Nothofagus menziesii</i>	Buttercup, native	<i>Ranunculus lappaceus</i>
Beetle, Christmas	<i>Anoplognathus</i> sp.	Butterfly, bay checkerspot	<i>Euphydryas editha</i>
Beetle, dung	Species of Scarabaeinae, Aphodiinae or Geotrupidae	Button-quail, little	<i>Turnix velox</i>
Beetle, grass grub	<i>Costelytra zealandica</i>	Buttons, scaly	<i>Leptorhynchus squamatus</i>
Beetle, red and blue	<i>Dicranolaius bellulus</i>	Cabbage tree	<i>Cordyline australis</i>
Belah	<i>Casuarina cristata</i>	Caladenia, pink	<i>Caladenia latifolia</i>
Bellbird	<i>Anthornis melanura</i>	Camel	<i>Camelus dromedarius</i>
Bentgrass	<i>Agrostis</i> sp.	Cane	<i>Saccharum officinarum</i>
Billy buttons	<i>Craspedia glauca</i>	Canola	Principally <i>Brassica napus</i>
Bindyi	<i>Sclerolaena</i> sp.	Carrot	<i>Daucus carota</i>
Bison	<i>Bison bison</i>	Cassia	<i>Senna</i> sp.
Blackberry	<i>Rubus fruticosus</i> species aggregate	Casuarina	<i>Casuarina</i> sp.
Blackbird	<i>Turdus merula</i>	Cat	<i>Felis catus</i>
Blackthorn	<i>Bursaria spinosa</i>	Cats-ear	<i>Hypochaeris radicata</i> or <i>H. glabra</i>
Blackwood	<i>Acacia melanoxylon</i>	Cattle	<i>Bos</i> sp.
Blowfly	Species of Calliphoridae	Cedar, red	<i>Toona ciliata</i>
Bluegrass	<i>Dichanthium sericeum</i>	Chaffinch	<i>Fringilla coelebs</i>
Bluegrass, floren	<i>Dichanthium aristatum</i>	Chamois	<i>Rupicapra rupicapra</i>
Bluegrass, Queensland	<i>Dichanthium sericeum</i>	Chat, orange	<i>Epthianura aurifrons</i>
Bollworm	<i>Helicoverpa punctigera</i> or <i>H. armigera</i>	Chat, white-fronted	<i>Epthianura albifrons</i>
Box	Species of <i>Eucalyptus</i> tree with 'box' (tessellated persistent rough) bark	Cherry	<i>Prunus</i> sp.
Box, grey	<i>Eucalyptus microcarpa</i>	Cherry, Jerusalem	<i>Solanum pseudocapsicum</i>
Box, Moonbi apple	<i>Eucalyptus malacoxylon</i>	Cherry, native	<i>Exocarpos cupressiformis</i>
Box, peppermint	<i>Eucalyptus odorata</i>	Chick pea	<i>Cicer arietinum</i>
Box, poplar	<i>Eucalyptus populnea</i>	Chicken	<i>Gallus domesticus</i>
		Chicory	<i>Cichorium intybus</i>
		Chloris	<i>Chloris</i> sp.
		Christmas tree, Western Australian	<i>Nuytsia floribunda</i>
		Cisticola	<i>Cisticola exilis</i>
		Cisticola, golden-headed	<i>Cisticola exilis</i>
		Clover	<i>Trifolium</i> sp.

Clover, red	<i>Trifolium pratense</i>	Earthworm	Species of Crassiditellata
Clover, white	<i>Trifolium repens</i>	Echidna	<i>Tachyglossus aculeatus</i>
Cockatoo	<i>Cacatua</i> sp.	Echinacea	<i>Echinacea</i> sp.
Cockatoo, glossy black	<i>Calyptorhynchus lathami</i>	Egret, cattle	<i>Ardea ibis</i>
Cockatoo, Major Mitchell's	<i>Lophochroa leadbeateri</i>	Egret, great white	<i>Ardea (alba) modesta</i>
Cocksfoot	<i>Dactylis glomerata</i>	Elderberry	<i>Sambucus nigra</i>
Coffee	<i>Coffea arabica</i>	Elephant	<i>Loxodonta</i> sp.
Common eutaxia	<i>Eutaxia microphylla</i>	Elk	<i>Cervus canadensis</i>
Cooba	<i>Acacia salicina</i>	Emu	<i>Dromaius novaehollandiae</i>
Cooba, river	<i>Acacia stenophylla</i>	Emu, Kangaroo Island dwarf	<i>Dromaius baudinianus</i>
Coolibah	<i>Eucalyptus coolabah</i>	Eremophila	<i>Eremophila</i> sp.
Copper-burr	<i>Sclerolaena</i> sp.	Fairy-wren	<i>Malurus</i> sp.
Coprosma	<i>Coprosma</i> sp.	Fairy-wren, superb	<i>Malurus cyaneus</i>
Corella, little	<i>Cacatua sanguinea</i>	Fairy-wren, variegated	<i>Malurus lamberti</i>
Cormorant, little pied	<i>Microcarbo melanoleucos</i>	Fairy-wren, white-winged	<i>Malurus leucopterus</i>
Corn, sweet	<i>Zea mays</i>	Falcon, black	<i>Falco subniger</i>
Cotton	<i>Gossypium hirsutum</i>	Falcon, bush	<i>Falco novaeseelandiae</i>
Creamy candles	<i>Stackhousia monogyna</i>	Falcon, eastern	<i>Falco novaeseelandiae</i> 'eastern'
Creeper, bridal	<i>Asparagus asparagoides</i>	Falcon, New Zealand	<i>Falco novaeseelandiae</i>
Creeper, Chilean flame	<i>Tropaeolum speciosum</i>	Fantail	<i>Rhipidura fuliginosa</i>
Cricket, black	<i>Teleogryllus commodus</i>	Fantail, grey	<i>Rhipidura albiscapa</i>
Crow	<i>Corvus orru</i> or <i>C. bennetti</i>	Featherhead	<i>Ptilotus macrocephalus</i>
Cuckoo-shrike	<i>Coracina novaehollandiae</i>	Fern, bracken	<i>Pteridium esculentum</i>
Curl grub	<i>Anoplognathus</i> sp.	Ferret	<i>Mustela putorius</i>
Curlew, long-billed	<i>Numenius americanus</i>	Ferret, black-footed	<i>Mustela nigripes</i>
Cypress	<i>Cupressus</i> sp.	Fescue	<i>Festuca</i> sp.
Cypress, Leyland	<i>Cupressus</i> × <i>leylandii</i>	Finch, red-browed	<i>Neochmia temporalis</i>
Daisy, Dorrigio	<i>Olearia flocktoniae</i>	Finch, zebra	<i>Taeniopygia guttata</i>
Daisy, everlasting	<i>Anaphaloidies bellidoidies</i>	Fir, Douglas	<i>Pseudotsuga menziesii</i>
Daisy, fragrant tree	<i>Olearia fragrantissima</i>	Firetail, beautiful	<i>Stagonopleura bella</i>
Daisy, fuzzy New Holland	<i>Vittadinia cuneata</i> var. <i>cuneata</i>	Firetail, diamond	<i>Stagonopleura guttata</i>
Daisy, mat	<i>Raoulia</i> sp.	Firetail, red-browed	<i>Neochmia temporalis</i>
Daisy, tree	<i>Olearia frimbriata</i>	Flatweed	<i>Hypochaeris radicata</i> or <i>H. glabra</i>
Daisy, yam	<i>Microseris lanceolata</i>		<i>Sminthurus viridis</i>
Daisy-bush, small-flowered	<i>Olearia microdisca</i>	Flea, lucerne	<i>Conyza</i> sp.
Damsel bug	<i>Nabis kinbergii</i>	Fleabane	Species of Asilidae
Daviesia	<i>Daviesia</i> sp.	Fly, robber	<i>Myiagra inquieta</i>
Deer, mule	<i>Odocoileus hemionus</i>	Flycatcher, restless	<i>Vulpes vulpes</i>
Deer, red	<i>Cervus elaphus</i>	Fox	<i>Pseudophryne pengilleyi</i>
Devil, Tasmanian	<i>Sarcophilus harrisii</i>	Frog, corroboree	<i>Litoria raniformis</i>
Devil's claw	<i>Ibicella lutea</i>	Frog, southern bell	<i>Eolophus roseicapillus</i>
Dichondra	<i>Dichondra</i> sp.	Galah	<i>Allium sativum</i>
Dingo	<i>Canis lupus</i> ssp. <i>dingo</i>	Garlic	<i>Geranium solanderi</i>
Diprotodon	<i>Diprotodon optatum</i>	Geranium, native	<i>Eucalyptus salubris</i>
Dog	<i>Canis familiaris</i>	Gimlet	<i>Petaurus australis</i>
Dogstail, crested	<i>Cynosurus cristatus</i>	Glider, yellow-bellied	<i>Glycine</i> sp.
Donkey orchid	<i>Diuris</i> sp.	Glycine	<i>Glycine latrobeana</i>
Doolan	<i>Acacia salicina</i>	Glycine, clover	<i>Glycine rubiginosa</i>
Dotterel	<i>Charadrius obscurus</i>	Glycine, twining	<i>Capra hircus</i>
Dragon lizard	Species of Agamidae	Goat	<i>Ulex europaeus</i>
Duck, blue	<i>Hymenolaimus malacorhynchus</i>	Gorse	<i>Vitis vinifera</i>
Eagle, Haast's	<i>Harpagornis moorei</i>	Grape	<i>Hordeum leporinum</i>
Eagle, wedge-tailed	<i>Aquila audax</i>	Grass, barley	

Grass, barnyard	<i>Echinochloa</i> sp.	Heliothis	<i>Helicoverpa armigera</i> or <i>H. punctigera</i>
Grass, blow-in	Species of Poaceae	Heliotrope, blue	<i>Heliotropium amplexicaule</i>
Grass, buffel	<i>Cenchrus ciliaris</i>	Heron, white	<i>Egretta alba modesta</i>
Grass, Chilean needle	<i>Nassella neesiana</i>	Hinau	<i>Elaeocarpus dentatus</i>
Grass, Coolatai	<i>Hyparrhenia hirta</i>	Hippopotamus	<i>Hippopotamus amphibius</i> or <i>Choeropsis liberiensis</i>
Grass, curly Mitchell	<i>Astrebla lappacea</i>	Honeyeater	Species of Meliphagidae
Grass, curly windmill	<i>Enteropogon acicularis</i>	Honeyeater, brown	<i>Lichmera indistincta</i>
Grass, fog	<i>Holcus lanatus</i>	Honeyeater, yellow-faced	<i>Lichenostomus chrysops</i>
Grass, hoop Mitchell	<i>Astrebla elymoides</i>	Hopbush	<i>Dodonaea</i> sp.
Grass, kangaroo	<i>Themeda australis</i> (syn. <i>T. triandra</i>)	Hops	<i>Humulus lupulus</i>
Grass, Parramatta	<i>Sporobolus creber</i>	Hornet	Species of Vespidae
Grass, silver	<i>Vulpia</i> sp.	Horse	<i>Equus caballus</i>
Grass, spear	<i>Austrostipa</i> sp.	Horse poison	<i>Indigofera dominii</i>
Grass, tall windmill	<i>Chloris ventricosa</i>	Huia	<i>Heterolocha acutirostris</i>
Grass, umbrella	<i>Chloris truncata</i>	Human	<i>Homo sapiens</i>
Grass, vetiver	<i>Chrysopogon filipes</i>	Indigo, Australian	<i>Indigofera australis</i>
Grass, wallaby	<i>Austrodanthonia</i> sp.	Ironbark, silver-leaved	<i>Eucalyptus melanophloia</i>
Grass, whisky	<i>Andropogon virginicus</i>	Iron-grass	<i>Lomandra</i> sp.
Grass, windmill	<i>Chloris truncata</i>	Ivy	<i>Helix hederæ</i>
Grasshopper	Species in the suborder Caelifera	Jacky winter	<i>Microeca fascians</i>
Greenfinch	<i>Carduelis chloris</i>	Kahikatea	<i>Dacrycarpus dacrydioides</i>
Ground sloth	Extinct sloths in the superorder Xenarthra	Kaka	<i>Nestor meridionalis</i>
Grouse	<i>Lagopus lagopus</i> ssp. <i>scoticus</i>	Kakapo	<i>Strigops habroptilus</i>
Grouse, sage	<i>Centrocercus urophasianus</i>	Kakariki	<i>Cyanoramphus</i> sp.
Guinea flower	<i>Hibbertia</i> sp.	Kale	<i>Brassica oleracea</i>
Gull, black-backed	<i>Larus dominicanus</i>	Kangaroo	<i>Macropus</i> sp.
Gum	Species of <i>Eucalyptus</i> tree with annually deciduous smooth bark	Kangaroo, eastern grey	<i>Macropus giganteus</i>
Gum, Bendemeer white	<i>Eucalyptus elliptica</i>	Kangaroo, giant	Extinct species of Macropodidae similar in size or larger than extant kangaroos
Gum, black	<i>Eucalyptus ovata</i>	Kanuka	<i>Kunzea ericoides</i>
Gum, Blakely's red	<i>Eucalyptus blakelyi</i>	Karamu	<i>Coprosma robusta</i>
Gum, blue	<i>Eucalyptus leucoxylon</i>	Kea	<i>Nestor notabilis</i>
Gum, candlebark	<i>Eucalyptus rubida</i>	Kereru	<i>Hemiphaga novaeseelandiae</i>
Gum, manna	<i>Eucalyptus viminalis</i>	Kingfisher	<i>Halycon sancta</i>
Gum, pink	<i>Eucalyptus fasciculosa</i>	Kite, black	<i>Milvus migrans</i>
Gum, river red	<i>Eucalyptus camaldulensis</i>	Kiwi, little spotted	<i>Apteryx owenii</i>
Gum, salmon	<i>Eucalyptus salmonophloia</i>	Kiwi, North Island brown	<i>Apteryx mantelli</i>
Gum, slaty red	<i>Eucalyptus glaucina</i>	Kiwifruit	<i>Actinidia deliciosa</i>
Gum, South Australian blue	<i>Eucalyptus leucoxylon</i>	Koala	<i>Phascolarctos cinereus</i>
Gum, spotted	<i>Corymbia maculata</i>	Kowhai	<i>Sophora molloyi</i>
Gum, sugar	<i>Eucalyptus cladocalyx</i>	Kowhai	<i>Sophora</i> sp.
Gum, Tasmanian blue	<i>Eucalyptus globulus</i>	Kurrajong	<i>Brachychiton populneus</i>
Gum, white	<i>Eucalyptus viminalis</i>	Lablab	<i>Lablab purpureus</i>
Harakeke	<i>Phormium tenax</i>	Lacebark, narrow-leaved	<i>Hoheria angustifolia</i>
Hardenbergia	<i>Hardenbergia violacea</i>	Lacewing, brown	<i>Micromus tasmaniae</i>
Harrier, Australasian	<i>Circus approximans</i>	Lacewing, green	<i>Mallada signatus</i>
Harrier, swamp	<i>Circus approximans</i>	Ladybird	Species of Coccinellidae
Hawkweed	<i>Hieracium</i> sp.	Ladybird, minute two-spotted	<i>Diomus notescens</i>
Hawkweed, mouse-ear	<i>Hieracium pilosella</i> (syn. <i>Pilosella</i> <i>officinarium</i>)	Ladybird, white-collared	<i>Hippodamia variegata</i>
Heather	<i>Calluna vulgaris</i>	Lancewood, fierce	<i>Pseudopanax ferox</i>
Hebe	<i>Hebe</i> sp.	Lantana	<i>Lantana camara</i>

Larch, European	<i>Larix decidua</i>	Native sarsaparilla	<i>Hardenbergia violacea</i>
Laurel, camphor	<i>Cinnamomum camphora</i>	Neanderthal	<i>Homo sapiens</i> ssp. <i>neanderthalensis</i>
Lavender	<i>Lavandula</i> sp.		<i>Quercus</i> sp.
Leaf-roller	<i>Epiphyas postvittana</i>	Oak	<i>Casuarina cunninghamiana</i>
Lettuce, wall	<i>Mycelis muralis</i>	Oak, river	<i>Themeda avenacea</i>
Lily, bulbine	<i>Bulbine bulbosa</i>	Oatgrass, native	<i>Avena sativa</i>
Lily, chocolate	<i>Dichopogon strictus</i>	Oats	<i>Avena fatua</i>
Lily, common vanilla	<i>Arthropodium strictum</i>	Oats, wild	<i>Clematis vitalba</i>
Lily, Darling	<i>Crinum flaccidum</i>	Old man's beard	<i>Olea europaea</i>
Linseed	<i>Linum usitatissimum</i>	Olive	<i>Allium cepa</i>
Lippia	<i>Phyla nodiflora</i> var. <i>nodiflora</i>	Onion	<i>Maclura pomifera</i>
Locust, honey	<i>Gleditsia triacanthos</i>	Orange, Osage	<i>Pterostylis</i> sp.
Long-worm	<i>Aporrectodea longa</i>	Orchid, greenhood	<i>Thelymitra</i> sp.
Lorikeet	Species of <i>Trichoglossus</i> or <i>Glossopsitta</i>	Orchid, sun	<i>Athene cunicularia</i>
Lovegrass	<i>Eragrostis</i> sp.	Owl, burrowing	<i>Sceloglaux albifacies</i>
Lovegrass, African	<i>Eragrostis curvula</i>	Owl, laughing	<i>Tyto novaehollandiae</i>
Lovegrass, paddock	<i>Eragrostis leptostachya</i>	Owl, masked	<i>Strix occidentalis</i> ssp. <i>caurina</i>
Lucerne	<i>Medicago sativa</i>	Owl, northern spotted	<i>Haematopus</i> sp.
Lucerne, Paddy's	<i>Sida rhombifolia</i>	Oystercatcher	<i>Panicum coloratum</i>
Macadamia	<i>Macadamia integrifolia</i> , <i>M.</i> <i>tetraphylla</i> or hybrids	Panic, bambatsi	<i>Digitaria brownii</i>
Magpie	<i>Cracticus tibicen</i>	Panic, cotton	<i>Panicum maximum</i> var. <i>trichoglume</i>
Mahoe	<i>Melicetyus ramiflorus</i>	Panic, green	<i>Pardalotus</i> sp.
Mallee, blue	<i>Eucalyptus polybractea</i>	Pardalote	<i>Pardalotus striatus</i>
Mallee, Kangaroo Island	<i>Eucalyptus cneorifolia</i>	Pardalote, striated	<i>Neophema chrysostoma</i>
Malleefowl	<i>Leipoa ocellata</i>	Parrot, blue-winged	<i>Psephotus pulcherrimus</i>
Manuka	<i>Leptospermum scoparium</i>	Parrot, paradise	<i>Psephotus haematonotus</i>
Matagouri	<i>Discaria toumatou</i>	Parrot, red-rumped	<i>Polytelis swainsonii</i>
Matai	<i>Prumnopitys taxifolia</i>	Parrot, superb	<i>Lathamus discolor</i>
Mat-rush	<i>Lomandra longifolia</i>	Parrot, swift	<i>Paspalum</i> sp.
Mat-rush, hard	<i>Lomandra multiflora</i> ssp. <i>dura</i>	Paspalum	Species of <i>Anoplognathus</i> , <i>Antitrogon</i> , <i>Rhopaea</i> or <i>Sericesthis</i> (Scarabaeidae)
Melaleuca	<i>Melaleuca</i> sp.	Pasture scarab larva	<i>Pisum sativum</i>
Melon, paddy	<i>Cucumis myriocarpus</i>		<i>Pisum sativum</i>
Merino	<i>Ovis aries</i>	Pea	<i>Arachis hypogaea</i>
Microlaena	<i>Microlaena stipoides</i>	Pea, field	<i>Carya illinoensis</i>
Millet	Summer forage crops of small- seeded grasses such as Japanese millet <i>Echinochloa</i> spp., hybrid and pearl millet <i>Pennisetum</i> spp. and foxtail millet <i>Setaria italica</i>	Peanut	<i>Hydrocotyle laxiflora</i>
Millet, native	<i>Panicum decompositum</i>	Pecan	<i>Tasmannia</i> sp.
Miro	<i>Prumnopitys ferruginea</i>	Pennywort, stinking	<i>Eucalyptus amygdalina</i>
Mistletoe, scarlet	<i>Peraxilla colensoi</i>	Pepperbush	<i>Eucalyptus nova-anglica</i>
Moonflower	<i>Selenicereus wittii</i>	Peppermint, brown	<i>Eucalyptus pulchella</i>
Morepork	<i>Ninox novaeseelandiae</i> ssp. <i>novaeseelandiae</i>	Peppermint, New England	<i>Phalaris</i> sp.
Moth, diamondback	<i>Plutella xylostella</i>	Peppermint, white	<i>Phascogale tapoatafa</i>
Moth, light-brown apple	<i>Epiphyas postvittana</i>	Phalaris	<i>Sus scrofa</i>
Mouse, Hastings River	<i>Pseudomys oralis</i>	Phascogale, brush-tailed	<i>Ocyphaps lophotes</i>
Mudfish, Canterbury	<i>Neochanna burrowsius</i>	Pig	<i>Columba livia</i> ssp. <i>domestica</i>
Myall, weeping	<i>Acacia pendula</i>	Pigeon, crested	Fruit-eating species of Australasian Columbidae
Myall, western	<i>Acacia papyrocarpa</i>	Pigeon, domestic	(<i>Columba</i> , <i>Macropygia</i> , <i>Leucosarcia</i> , <i>Ptilinopus</i> and <i>Lopholaimus</i>)
Myna, common	<i>Acridotheres tristis</i>	Pigeon, fruit	<i>Pinus</i> sp.
		Pine	

Pine, bare-rooted	<i>Pinus radiata</i>	Robin, perch-and-pounce	Species of <i>Petroica</i> , <i>Melanodryas</i> or <i>Eopsaltria</i>
Pine, Caribbean	<i>Pinus caribaea</i>	Rolypoly	<i>Sclerolaena muricata</i>
Pine, Corsican	<i>Pinus nigra</i>	Rolypoly, black	<i>Sclerolaena muricata</i>
Pine, cypress	<i>Callitris</i> sp.	Rosella	<i>Platycercus</i> sp.
Pine, hoop	<i>Araucaria cunninghamii</i>	Rosella, eastern	<i>Platycercus eximius</i>
Pine, longleaf	<i>Pinus palustris</i>	Rosewood	<i>Dysoxylum fraserianum</i>
Pine, radiata	<i>Pinus radiata</i>	Rosewood, western	<i>Alectryon oleifolius</i>
Pink fairy	<i>Caladenia latifolia</i>	Rust fungus	<i>Puccinia myrsiphylli</i>
Pinrush	<i>Juncus</i> sp.	Ryegrass	<i>Lolium perenne</i>
Piopio	<i>Turnagra capensis</i> ssp. <i>tanagra</i>	Ryegrass, annual	<i>Lolium rigidum</i>
Pipit	<i>Anthus novaeseelandiae</i>	Sagebrush	<i>Artemisia tridentata</i>
Pipit, Australasian	<i>Anthus novaeseelandiae</i>	Sagg	<i>Lomandra longifolia</i>
Pittosporum	<i>Pittosporum</i> sp.	Saltbush	<i>Atriplex nummularia</i>
Platypus	<i>Ornithorhynchus anatinus</i>	Saltbush, bladder	<i>Atriplex vesicaria</i>
Plover	<i>Vanellus miles</i> ssp. <i>novaehollandiae</i>	Saltbush, climbing	<i>Einadia nutans</i>
Poa, tussock	<i>Poa sieberiana</i>	Saltbush, creeping	<i>Atriplex semibaccata</i>
Pohuehue	<i>Muehlenbeckia</i> sp.	Saltbush, Mueller's	<i>Atriplex muelleri</i>
Pokaka	<i>Elaeocarpus hookerianus</i>	Saltbush, old man	<i>Atriplex nummularia</i>
Pomaderris, Kangaroo Island	<i>Pomaderris halmaturina</i> ssp. <i>halmaturina</i>	Salvation jane	<i>Echium plantagineum</i>
Poplar	<i>Populus</i> sp.	Sawfly, eucalypt	Species of <i>Perga</i> or <i>Pseudoperga</i>
Possum, brushtail	<i>Trichosurus vulpecula</i>	Scarlet runner	<i>Kennedia prostrata</i>
Possum, Leadbeater's	<i>Gymnobelideus leadbeateri</i>	Sea-eagle, white-bellied	<i>Haliaeetus leucogaster</i>
Potato	<i>Solanum tuberosum</i>	Sheep	<i>Ovis aries</i>
Prairie dog, black-tailed	<i>Cynomys ludovicianus</i>	Shelduck, paradise	<i>Tadorna variegata</i>
Prickly pear	<i>Opuntia stricta</i>	Sheoak	<i>Allocasuarina verticillata</i>
Privet	<i>Ligustrum lucidum</i>	Sheoak, drooping	<i>Allocasuarina verticillata</i>
Pronghorn	<i>Antilocapra americana</i>	Shotgrass	<i>Paspalidium globoideum</i>
Pukatea	<i>Laurelia novae-zelandiae</i>	Silvereye	<i>Zosterops lateralis</i>
Pukeko	<i>Porphyrio porphyrio</i>	Songlark	<i>Cincloramphus</i> sp.
Quail	Species of <i>Turnix</i> or <i>Coturnix</i>	Songlark, brown	<i>Cincloramphus cruralis</i>
Quail, stubble	<i>Coturnix pectoralis</i>	Sorghum	<i>Sorghum bicolor</i>
Rabbit	<i>Oryctolagus cuniculus</i>	Sorghum, silk	<i>Sorghum</i> sp. hybrid cultivar
Rape	<i>Brassica napus</i>	Sorghum, wild	<i>Sorghum leiocladum</i>
Rat, black	<i>Rattus rattus</i>	Sorrel, wood	<i>Oxalis perennans</i>
Rat, Norway	<i>Rattus norvegicus</i>	Soursob	<i>Oxalis pes-caprae</i>
Rat, Pacific	<i>Rattus exulans</i>	Spaniard	<i>Aciphylla</i> sp.
Raven	<i>Corvus coronoides</i> , <i>C. tasmanicus</i> or <i>C. mellori</i>	Spinach	<i>Spinacea oleracea</i>
Redgrass	<i>Bothriochloa macra</i>	Spyridium, MacGillivray's	<i>Spyridium eriocephalum</i> var. <i>glabrisepalum</i>
Redpoll	<i>Carduelis flammea</i>	Starling	<i>Sturnus vulgaris</i>
Redwood, coast	<i>Sequoia sempervirens</i>	Stilt, black	<i>Himantopus novaezelandiae</i>
Rewarewa	<i>Knightia excelsa</i>	Stilt, pied	<i>Himantopus himantopus</i>
Rhinoceros	<i>Ceratotherium</i> sp.	Stoat	<i>Mustela erminea</i>
Rhynchosia	<i>Rhynchosia minima</i>	Stone-curlew, bush	<i>Burhinus grallarius</i>
Rice	<i>Oryza sativa</i>	Strawberry	<i>Potentilla</i> × <i>ananassa</i>
Riceflower, yellow	<i>Pimelea flava</i> ssp. <i>flava</i>	Stringybark	Species of <i>Eucalyptus</i> tree with thick persistent fibrous bark
Rice-grass, weeping	<i>Microlaena stipoides</i>	Subclover	<i>Trifolium subterraneum</i>
Rifleman	<i>Acanthisitta chloris</i>	Sugarcane	<i>Saccharum officinarum</i>
Rimu	<i>Dacrydium cupressinum</i>	Sun orchid, blue	<i>Thelymitra nuda</i>
Robin, eastern yellow	<i>Eopsaltria australis</i>	Sun orchid, pink	<i>Thelymitra rubra</i>
Robin, New Zealand	<i>Petroica australis</i>	Sun orchid, scented	<i>Thelymitra nuda</i>

Sundew, pale	<i>Drosera peltata</i>	Turnip	<i>Brassica rapa</i> ssp. <i>rapa</i>
Sunflower	<i>Helianthus annuus</i>	Turpentine	<i>Eremophila sturtii</i>
Sunray, hoary	<i>Leucochrysum albicans</i> var. <i>tricolor</i>	Tussock, red	<i>Chionochloa rubra</i>
		Tussock, silver	<i>Poa cita</i>
Swallow, welcome	<i>Hirundo neoxena</i>	Vetch	<i>Vicia sativa</i>
Swan	<i>Cygnus atratus</i>	Vine, native jasmine	<i>Parsonsia</i> sp.
Swan, black	<i>Cygnus atratus</i>	Vine, peach	<i>Ipomoea lonchophylla</i>
Sycamore	<i>Acer pseudoplatanus</i>	Vine, pumpkin	<i>Ibicella lutea</i>
Tagasaste	<i>Chamaecytisus palmensis</i>	Vine, yellow	<i>Tribulus micrococcus</i>
Tarvine	<i>Boerhavia dominii</i>	Wallaby, swamp	<i>Wallabia bicolor</i>
Tawa	<i>Beilschmiedia tawa</i>	Wandering Jew	<i>Tradescantia flavesces</i>
Tea	<i>Camellia sinensis</i>	Warbler, grey	<i>Gerygone igata</i>
Tea tree	<i>Melaleuca alternifolia</i>	Warbler, speckled	<i>Chthonicola sagittata</i>
Tea tree, dryland	<i>Melaleuca lanceolata</i>	Wasp, scoliid	Species of Scoliid
Tea tree (eastern Australian rainforest succession)	<i>Leptospermum</i> sp.	Wasp, tiphiid	Species of Tiphidae
Tea tree (SA)	<i>Melaleuca</i> sp.	Wattle	<i>Acacia</i> sp.
Termite	Species of Termitidae	Wattle, Deane's	<i>Acacia deanei</i>
Tern	<i>Sterna</i> sp.	Wattle, hickory	<i>Acacia implexa</i>
Thar	<i>Hemitragus jemlahicus</i>	Wattle, sally	<i>Acacia melanoxylon</i>
Thistle, saffron	<i>Carthamus lanatus</i>	Weasel	<i>Mustela nivalis</i>
Thornbill	<i>Acanthiza</i> sp.	Weebill	<i>Smicornis brevirostris</i>
Thornbill, brown	<i>Acanthiza pusilla</i>	Weta, giant	<i>Deinacrida</i> sp.
Thornbill, yellow	<i>Acanthiza nana</i>	Wheat	<i>Triticum</i> sp.
Thrip, Kelly's citrus	<i>Pezothrips kellyanus</i>	Wheat-grass, native	<i>Elymus scaber</i>
Thrush, Bassian	<i>Zoothera lunulata</i>	Whistler, golden	<i>Pachycephala pectoralis</i>
Thrush, song	<i>Turdus philomelos</i>	Whistler, olive	<i>Pachycephala olivacea</i>
Thylacine	<i>Thylacinus cynocephalus</i>	Whistler, rufous	<i>Pachycephala rufiventris</i>
Titoki	<i>Alectyron excelsa</i>	Wilga (shrub)	<i>Geijera parviflora</i>
Tomtit	<i>Petroica macrocephala</i>	Willie wagtail	<i>Rhipidura leucophrys</i>
Tororaro, shrubby	<i>Muehlenbeckia astonii</i>	Wiregrass	<i>Aristida ramosa</i>
Totara, lowland	<i>Podocarpus totara</i>	Woodpecker, red-cockaded	<i>Picoides borealis</i>
Treecreeper, brown	<i>Climacteris picumnus</i>	Woodruff, common	<i>Asperula conferta</i>
Trout	Species of <i>Oncorhynchus</i> or <i>Salmo</i>	Woodswallow, dusky	<i>Artamus cyanopterus</i>
		Woodswallow, white-browed	<i>Artamus superciliosus</i>
Tuatara	<i>Sphenodon punctatus</i>	Worm, grey	<i>Aporrectodea caliginosa</i>
Tuberculosis, bovine	<i>Mycobacterium bovis</i>	Worm, southern	<i>Aporrectodea trapezoides</i>
Tui	<i>Prosthemadera novaeseelandiae</i>	Yanganbil (grass)	<i>Austrostipa bigeniculata</i>
Tulip, cape	<i>Moraea flaccida</i> or <i>M. miniata</i>	Yellow star	<i>Hypoxis vaginata</i>

Note: Scientific names of Australian plants were sourced from The Royal Botanic Gardens and Domain Trust (2012) *PlantNET* – The Plant Information Network System of The Royal Botanic Gardens and Domain Trust, Sydney, Australia (version 2.0), <<http://plantnet.rbgsyd.nsw.gov.au>>. Names of Australian plants not listed in PlantNET and of Australian animals were based on the Atlas of Living Australia (2012) <www.ala.org.au>. Names of Australian fossils were based on Australian Museum (2012) *Australia's Extinct Animals*, <<http://australianmuseum.net.au/Australias-extinct-animals>>. Crop and forage plant names and those of pest and beneficial invertebrates not listed above were sourced from the NSW Department of Primary Industries (2012) <www.dpi.nsw.gov.au>. New Zealand plant and animal names were sourced from Ngā Tipu o Aotearoa (2012) *New Zealand Plants*, <<http://nzflora.landcareresearch.co.nz>>; King CM (2005) *The Handbook of New Zealand Mammals*, 2nd ed., OUP, Melbourne; and Ornithological Society of New Zealand (2012) *New Zealand Recognised Bird Names (NZRBN) Database*, Wellington, NZ, <<http://bird.org.nz/nzrbn.htm>>. Species not listed by the above authorities were sourced from International Union for the Conservation of Nature (2012) *The IUCN Red List of Threatened Species, Version 2011.2.*, Gland, Switzerland, <www.iucnredlist.org>. All websites were accessed in May 2012.

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